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Cognitive Didactics: Hyper-Constructivistic Knowledge Building

Abstract: *The crisis in teaching Science (and not only) triggered the implementation – of previously developed concepts, like constructivism, cognitivism, pedagogical contents knowledge, inquiry-based teaching. We combine these ideas into hyper-constructivistic didactics, in which knowledge (and competence) are constructed with pupils, but under teacher's wise guidance. Neo-realism, i.e. the extensive illustration of phenomena by experiments, complements this approach.*

Keywords:

Motivation: need for renewed Pedagogy

The European Union already identified serious problems in Science education about ten years ago. So-called Rocard's Report (2007) showed that the number of graduates in physical sciences in the Netherlands, France and Germany fell by 40–50 % between 1994 and 2003. The subtitle of that report sounds significant: "A Renewed Pedagogy for the Future of Europe".

Stimulated by this report, some countries (and the EU in its whole) undertook efforts aimed at increaing the number of students in Science. Examples, say of Poland, showed that the effectiveness of these actions was limited to their exact (financial) duration and did not bring a "renewed pedagogy". This is to be attributed to essentially "palliative" activities (extra scholarships to students, extra money for tutoring etc.) that did not change the contents and ways of teaching science. Students are expected to reproduce the knowledge transferred to them and any independent thinking is not well-seen. Even if Polish teachers would prefer the constructivistic approach, see fig. 1, their potential attitudes do not translate into education practices: Polish schools (and teachers) are ranked almost exclusively according to formal requirements (percentage of passed exams, see fig. 2.) rather than on the basis of innovative ways of teaching.

Italian teachers, in turn, do not declare clear preferences regarding the two styles of teaching (or alternatively, they present a broader variety of styles, as the comparison is *ipsative*). Strong criticism on traditional teaching was also expressed in the UK (Brand, 2011): "For many elementary teachers, teaching science primarily involves worksheets and definition". Even stronger words on the school system as a whole came from Harrison (2004):

> *The present system does not meet the needs of any but a small minority of the students I teach. It is based on a specification of content in the National Curriculum that requires students to memorize and repeat facts about scientific knowledge that are of little interest or relevance to them. It does not prepare them to understand the scientific issues that will meet in everyday life.*

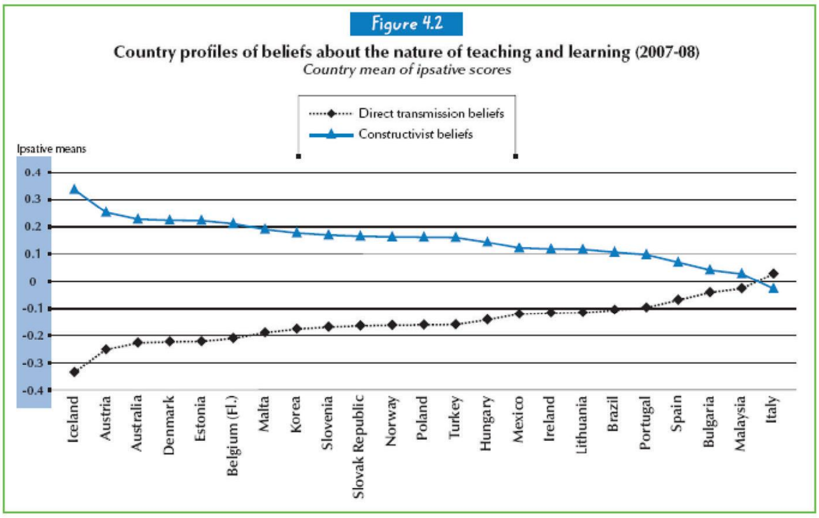

Figure 1. Beliefs as declared by teachers: direct transmission vs constructivism (OECD, TALIS, 2009).

It is also quite commonly believed that present school systems are such as all pupils, starting from primary school, would become scientists as adults. Do we really need all these scientists?

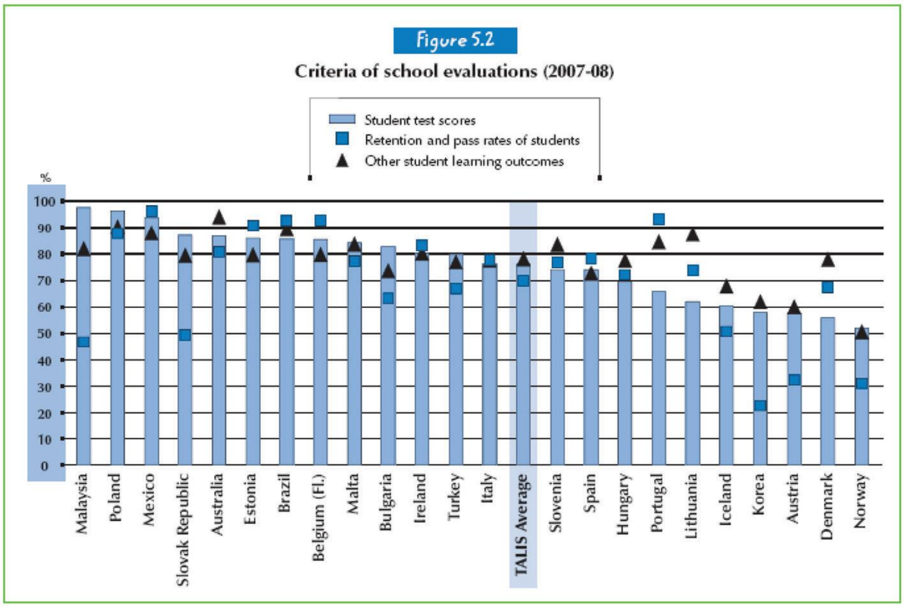

Figure 2. Criteria of school evaluations. Polish (and also Portugal) schools belong to the most formally evaluated among all compared countries. From: OECD (TALIS, 2009).

Constructivism: social roots

Numerous approaches to teaching and learning meet with a public response and, in consequence, become indicators for official educational policies. Constructivism is one of such approaches; it is usually referred to its social meaning: knowledge is a social construct. The basis for the construction process is "common thinking", and knowledge comes as the result of a social agreement, so it requires social acceptance (and an institution that codifies and defends it).

We note that strict referring to the social constructivism would lead to *epistemological relativism*, and cannot be accepted in view of scientific realism: we assume that objective, or at least desirably objective truth does exist and the teacher should tend to show it to students. Possible "partial" truths are only steps to the final statement that the teacher planned before the lesson. Scientific "truth" that would correspond solely to the outcome of common thinking cannot be accepted. Therefore, we propose to go beyond such a "free-run" constructivism, towards using common knowledge only as a starting point, and to construct knowledge under the strict guidance of the teacher/ trainer/ educator. We call this approach "hyper-constructivism" (Karwasz 2011).

Anyhow, the works of Berger and Luckmann (1966) brought an important insight into the *social perception* of knowledge. It is not *objective* truth that influences human actions but the *social perception* of this knowledge. They wrote (p. 19):

> *Everyday life presents itself as a reality interpreted by men and subjectively meaningful to them as a coherent world. As sociologists we take this reality as the object of our analysis. Within the frame of reference of sociology as an empirical science it is possible to take this reality as givem to take as data particularly phenomena arising within it, without further inquiring about the foundations of this reality, which is a philosophical task.*

Thus, we draw practical conclusion for the hyper-constructivistic teaching: truth, or partial truths, in order to be fixed in minds, first need psychological acceptance by all individuals in the group. Knowledge, in order to be assimilated, needs emotional support.

Cognitivism – science on human understanding

By the term "cognitivism" a common domain of different disciplines – both human (philosophy) and experimental (psychology, neurosciences) is intended. For didactics, cognitivism means an essential change of paradigm: the subject of teaching is not specific knowledge, but its state of *understanding in the mind* of a young person. In other words, during the lesson it is not the sequence of equations to be written that scans time, but the *reflected* knowledge, as seen in the eyes of students: any brake in understanding terminates the lesson. The point of interest of cognitive teaching and learning is not a scientific subject itself but its *representation* in students' mind.

Different authors stress various aspects of cognitivism. Jerome Bruner in his late "Acts of meaning" (1990, p. 8) wrote:

> *The cognitive revolution as originally conceived virtually requires that psychology join force with anthropology and linguistics, philosophy and history, even with the discipline of law. [...]. Very early on, for example, emphasis began shifting from „meaning" to „information", from the construction of meaning to the processing of information.*

Piero Crispiani (2006, p. 8) gives a following definition of cognitive didactics:

> *Cognitive didactics in not a single method, is not based on one procedure or protocol, but accumulates a series of statements and doubts on the [didactical] observations themselves, and appeals to the previous knowledge – from neuro-psychology to pedagogy, ethology, sociology etc. – to the most reliable aspects of the reasoning, i.e. the human mind."*

In practical didactical applications, a cognitivist method means to consider not only the final goal of a lesson but a *path* of arrival to this goal, or even more: many *possible* paths of arrival.

Cognitivist didactics is to be completed with cognitivist *pedagogy* (Siemieniecki, 2013), which streses the general importance of communication: ways of "packing" information, ways of transmission, modes of receiving.

> *In this way, communication creates the reality. The situation indicates communication and communicating as fundamental notions, that must find within subjects of cognitive pedagogy. There is not didactical nor educations activity without communicating. That is communication which defined the structure, re-organization and processing of social fact.* (p. 76)

Pedagogical Knowledge Contents

What is another factor necessary for obtaining high didactical efficiency, is the equilibrium between scientific knowledge and pedagogical competences of the teacher. Lee Shulman (1987), evoking an educational reform, indicated that, apart from the knowledge of subject contents, general pedagogical and curriculum content knowledge, teachers must show a special ability: pedagogical content knowledge

> *Among these categories, pedagogical knowledge is of special interest because it identifies the distinctive bodies of knowledge for teaching. It represents the blending content and pedagogy into an understanding of how particular topics, problems, or issues are organized, represented, and adapted to the diverse interests and abilities of learners, and presented for instruction.* (p. 8)

Teachers must understand pupils and their needs, but also "educational ends, purposes, and values, and their philosophical and historical grounds". We call this requirement a "9:1 rule": the teacher must know not only specific information to be transferred to the student, but also its whole *entourage* – the history of the discovery, alternative laws, limits of applicability, practical impacts, possible wrong explanations etc. What we also adapt from PCK is the convction, that pedagogical constraints (and pedagogical goals) are not less important in teaching than scientific contents themselves, see Abell (2008).

Inquiry-based teaching

Inquiry-based teaching (IBT), as stated by Shelley Goldman (1998, p. 258), has always been present in educational systems, also in USA, but usually reserved for higher-level social groups: "For most of this century, our educational system served only the elite in thinking-centered classrooms. The majority of students received an education aimed at the acquisition of basic skills and routine knowledge." A few years ago, IBT also became an indication for EU.

A variation of IBT, particularly applicable on physics, see for ex. Fazio, 2003), is so-called PEC (Prediction → Experiment → Comparison) methodology. Students are asked to predict the outcome of an experiment; this resembles a constructive, inquiry-based methodology. "A conducting wire is placed near a magnet. What will happen if an electric current is supplied to the wire?" For sure something will happen – probably the wire will move. A series of “left” or “right hand” rules governs the direction of this movement, and say, again in Polish school, these rules become a part of competence tests. So, even PEC itself does not sufficiently stimulate students’ ability to create and resolve new situations.

All these approaches have been recently criticized for being not much efficient in long-term educational goals: learning by discovering, with weak instructions lead to poorer results than traditional teaching (Kirchner, 2006). Moreover, some tests showed that unguided students can perform worse after learning than before: mental processes during acquiring knowledge are different from doing research. Therefore, not denying the achievements of constructivism and IBT, the leading role of an adequately prepared teacher comes inevitably back. Students still can construct their knowledge in an (apparently) independent way, but the teacher/ trainer/ needs to supervise that their cognitive processes go towards the pre-defined didactical goal.

Hyper-constructivism: principles

All this discussion, and first of all the requirement to form adults capable to adapt to changing cultural conditions, lead to a new strategy: learning by self discovering, but under the guidance of a teacher/ trainer, well-prepared both scientifically and pedagogically. There is also a second requirement: in present, virtual worlds, it is necessary to come back to really existing, tangible objects. Real objects – a page in a book, a physical object – fix the cognitive attention for a longer time than internet pages that swap within half a second.

Two strategies

These two main strategies:

1) constructing knowledge by pupils, but under the strict and wise control of the teacher
2) using all available (i.e. really existing) resources – objects, experiments, books, internet we define as:
   - **hyper-constructivism** (i.e. going beyond the social constructivism, in which knowledge is merely discussed and socially accepted)

- **neo-realism** – all what can be shown (seen, touched), must be shown, and even more.

The latter of these indications goes beyond what Albert Einstein used to say: "Everything should be explained as simple as possible but not simpler". We say: "Everything should be explained as simple as ever *impossible*, in a way, that everyone can understand it". We show not only falling balls, but also an electron (lepton) as a Greek euro-cent (ΛΕΠΤΟ) and proton (an iron cube, with three animal-like quarks on three corresponding walls and of a mass in proportion to the lepton). Giving a visualization stimulates pupils imagination: quarks posses their features, and we need to report them; also the Earth, seen by Voyager far away seems a faint, blue point.

Hyper-constructivism: principles

- Information is pan-available
- Teaching is *interactive*
- Elements of individual knowledges of students are the starting *resource*
- First, it is the teacher who defines *implicitly* the arrival goal (i.e. a law, a principle, a phenomenon)
- Such a heuristic goal corresponds to an *ontological category* (Kant)
- Teacher has to *induce* this category in minds of student
- The arrival *path* is defined (case-by-case*) according* to the knowledge of the audience
- In constructing the arrival path, the teacher uses knowledge available in the target group and *ad-hoc* experiments (or texts in teaching languages, history, philosophy)
- Learning becomes an active (and involving) discovery

HC didactic rules are similar to the traditional didactics, but completely different:

- Frequently proposed activity of students is substituted by *autonomous* constructing in school/ extra-school group, of a fragment of knowledge that was planned by the teacher.
- Students/ pupils construct this knowledge themselves, based on possessed resources (own information, experiments, internet, books at hand).

- The teacher solely streams their group thinking in the planned direction.
- In case of difficulties, the teacher does not say: „Wrong! Sit down!" but asks questions in such a way that the student and/or his/her colleagues find the error themselves.
- Obviously, it requires the huge resources of knowledge and experience of the teacher. In physics, additionally – many different experiments at hand.

The difference between HC and IBT is that, giving an experiment to students, first we say "please do something!". –"What shall I do?" they ask. "Anything you want!". Showing what to do would spoil independent thinking. As stated by Polish pedagogist, Kazimierz Sośnicki, "Too much visualizations (exemplifications) lead to infantilism."

We take the *common thinking* from constructivism as a starting point for the construction of desirable knowledge. We do not disregard this thinking as wrong pre-concepts (Duit, 2006): these are objectively existing social facts, which must be accounted for in constructing "correct" knowledge. Say, pupils' convinction that heavier objects fall quicker than light ones is a useful base for the construction of a didactic path. Using the "filled-up" (Popper's expression) notion that "objects fall because of gravity" not only does not explain anything (as "gravity" it means being heavy), but it also spoils, already at the beginning a possible *cognitive* path.

A hyper-constructivist path starts from common thinking (heavier objects fall quicker), but proceed via a series of experiments on light and heavier balls falling. First, a ping-pong ball falls from about half a meter. However, the abstraction of non essential observables is the essence of scientific experiments. Therefore, we perform this experiment asking students to close their eyes and listen which sound is first: ping-pong or caoutchouc. Like in a real experiment, we repeat this trial twice (and not more) – the third, cross-checking trial is with their eyes open.

HC – resume':

1) Teaching objectives (knowledge and cognitive skills) are thoroughly defined, with long preparation (for. ex. the concept of *energy*)
2) Common thinking, i.e. pre-existing knowledge is the starting point ("objects fall because they are heavy")

3) A set of steps (and alternative paths) is also well defined: discussion with students is the way to get the final construct
4) at-spot available knowledge (via internet, books, experiments) is used to achieve the fixed points of knowledge ("kinetic energy can be transformed into potential and vice versa").

We stress another aspect of hyper-constructivistic path: student start from a variety of (common) thoughts, and the teacher links them into a coherent reasoning. Differently from social constructivism, from IBT and PEC approaches, students are the active particpant of all actions: defining problem, projecting experiment, performing it, explaining, evaluation of wrong answers, drawing conclusions, asking further open questions.

At all steps, students are not left for a free-lance discussion ("who will say more?"), but are *strictly guided* by the teacher ("do you agree with this answer? Can we find-out why?"). This, in turn, reflects Kant's epistemology: the scientists do not ask the nature like a child "what is this", but like a magistrate – "is that truth, than on May 1st, in Sopot, on Kujawska street, you stabbed Jan Kowalski Yes? or No?". The nature usually answers "Ni" – neither Si nor No, and HC teaching should also warn students about it.

Teaching in school and outside school

Hyper-constructivist narration on science has been developed in a series of our actions outside school: i) introductive lectures and training for teachers and guides at interactive exhibitions, ii) at workshops and plenary lectures for kids at universities, iii) at interactive lectures in science museums. Such activities, for groups that each time present different preparation, without fixed curricula obligations and with no strict limits of time, constitute natural playgrounds for plastic and interesting narration.

On the other hand, the practical applications of IBT in schools clash not only with the administrative requirements of authorities (see again fig. 2) and with the lack of time, but also with the lack of skills, which can be accumulated only with long pedagogical experience. As stated by van Uum et al. (2016): "For primary school teachers, the open nature of IBSE poses challenges as they often lack experience in supporting their pupils during the different phases of an open IBSE project, such as formulating a research question and designing and conducting an investigation."

Further more, it is not enough to propose IBT without inducing socio-cultural changes in teachers, actions (Brand 2011). This is the crucial point linking to an apparently contradictory analysis in fig. 1 and 2: Polish teachers declare the will to introduce constructivist approaches and the practice is just opposite. Deeper cultural changes are needed in teachers' thinking – a variety of long-term actions are necessary to achieve such changes.

Teaching outside school allows extending the educational aims outside fixed national curricula, towards diversified practical and social abilities. As stated by Hudson (2003):

> *Informal learning experiences are particularly well positioned to facilitate the affective and social components of learning. They can provide the fusion of the cognitive, affective and social that is too often absent in the classroom but is essential to the kind of radical shift in attitudes and values on which sociopolitical action depends. It is also well established that education in and through the environment can play a substantial role in assisting the re-ordering of values and the development of new ones.*

Learning is Fun

The overflow of information (and the rigidity of the school, we recall fig. 2) makes learning not much loved by pupils. To greater extent, therefore, an effort has to be made to make learning exciting. As the founder of didactics as a science, Jan Komensky, wrote in his "Great Didactics" in 1657 (&18): "and the subjects will attract students if they correspond to pupils, capacities and are presented clearly, and particularly if we interweave with matters joyful or less important". Adding fun, makes possible teaching complex notions, even in physics, and even for children (Karwasz 2011, 2015).

The success of these initiatives is, however, not due to their "joyful" elements, but thanks the didactic and scientific contents. As resumed in (Karwasz, 2012), the three cognitive aspects of the object/ lesson/ lecture/ rehearsal: lucid + didactic + scientific must be in mutual equilibrium, like white light is composed of three fundamental colours. Reducing teaching to be "pleasant" makes it, in longer term, ridiculous and useless.

Among the competences that should be developed in this mutually complementary approach, we recall those from OECD (AHELO, 2014): – critical thinking, – analytical reasoning, – problem solving, – written (and oral) communication.

Conclusions

The need for new pedagogy, well identified both in Europe and in America, comes from new technological and cultural circumstances. The background for the reform started growing as early as in the second half of 19th century, as concepts of constructivism, cognitivism, pedagogical contents, inquiry-based teaching and so on. However, different implementations did not bring a significant breakthrough in efficiency of educational systems. This, as shown by numerous studies, including those by OECD, stem from the gap between potential attitudes and practical implementations. Therefore, science teachers at all levels of educations, both formal and informal, should be the primary target group of new methodologies.

The detailed goals of the proposed methodology coincide with the current indications from EU (and OECD) institutions: "communication in mother language, communication in foreign languages, competences in STEM (science, technology, mathematics) and informatics (digital reality), lean to learn, social and civic competences, spirit of initiative and enterprise, cultural consciousness and expression" (Da Re, 2015). In other words: not only the contents, but a wide range of attitudes and abilities needed in adult life.

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