Activity-based introductory curriculum for mastering initial competencies: Natural Sciences for urban students

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Abstract. Acquiring and mastering initial competencies in Natural Sciences is especially hard for urban students, as their personal experience concerning the domain is poor and contradictory. While the researchers emphasize the importance of hands-on experiments, inter-domain integration and real-life contexts, the design of a consistent framework for introducing students to Natural Sciences is still a challenge. Based on the Cultural-historical theory (Vygotsky) and the Developmental instruction (Davydov) we have designed an activity-based introductory Natural Sciences curriculum for 5th-graders and tested it in our previous studies. In our new pilot teaching project we adapted our materials to primary education to examine the earliest stages of initial competencies formation. The experimental class (20 students, 6-7 years old) had three lessons a week within their regular schedule. Classroom observations, students' materials, quizzes, tests, audio-taped classroom discussions, teacher's diary were used as data source for qualitative analysis. In this paper a sample fragment on making bread is presented alongside with students' works and discussion. The results are discussed in terms of "shifts" in formation of initial competencies, which we observed during the year. The formation of modelling (which we consider to be the central competency, based on our analysis) demands a thorough attention in future studies.
Keywords: primary education, initial competencies, qualitative analyses.

1 Introduction

Modern urban life of a "consumer" impedes learning Natural Sciences: students like to listen, watch and read about "discoveries and inventions", but they experience enormous difficulties in a thorough study of the essence of the observed phenomena. There is also an illusion of "availability": a student believes that any knowledge is within "one click" reach. On the other hand, school education is presenting "ready-made" knowledge, which seems to be answering questions that are not asked by students.

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To our mind, urban students are especially vulnerable, as they have little personal experience with the phenomena, which Natural Sciences deal with, and the modern technologies are too specialized for any child to understand or participate. Moreover, “everyday concepts”, acquired casually, often contradict scientific ones [1] and systematically impede students’ promotion in Natural Sciences.

A demand for a sound Natural Science education, which scaffolds students’ own learning activity is urgent and is expressed both: in Russian and in foreign “standards” of education [2-5]. Researchers suggest a variety of ways to boost Natural Science learning, among which STEM-integration is most popular [6-8]. Studies focus on the role of hands-on experiments within everyday, industrial or historical contexts, and the role of modelling skills [9-11].

Following the principles of Developmental Instruction theory [12], we have devised the “humanitarian” introductory curriculum for Natural Sciences based on testing ancient technologies. The core progression looks as follows: a) learning about ancient technologies from texts and testing them in a class lab (How did they do it?); b) acquiring special symbolic tools for the domain (How did they think about it to make it work and to pass the technology over generations?); c) assimilating the meanings behind the procedures and “human values” (Why did they do it?). After we have tested it through several cycles with students of the 5th grade, we have decided to examine the initial competencies’ acquisition in detail. For this purpose we adapted our materials and conducted a one-year teaching cycle in the 1st grade, as the earliest steps of competencies’ are the most extended ones – and thus most available for analysis. Our research question was: whether our approach to activity-based curriculum design, embedded in the introductory Natural Sciences curriculum, provides support for initial competencies’ acquisition and mastering at the very first stages of school education.

2 Methods

Within the cultural-historical approach we exploit the “genetic experiment” method [1]: to explore the psychological mechanism of the concept formation, we devise a tentative learning progression and conduct a teaching experiment to test, whether our instruction provides for the needed concept’s acquisition. Our experimental class of 20 students of the 1st grade (10 boys and 10 girls) from a regular Moscow school was taught after the introductory Natural Science curriculum [13] during one school year three times a week (99 lessons in total). Classroom observations, students' materials, quizzes, tests, audio-taped classroom discussions, teacher’s diary were used as data sources.

We will now describe a sample fragment in which students were challenged with the task to design the technological chart which tells, how to make bread. The text, which settles the problem and contains the technology description, is the folk tale “Easy dough” about a wolf, who asks a mower, how to make bread. The technological chart is drawn from the final product (bread) towards the raw nature material, which is transformed into it through a series of operations.

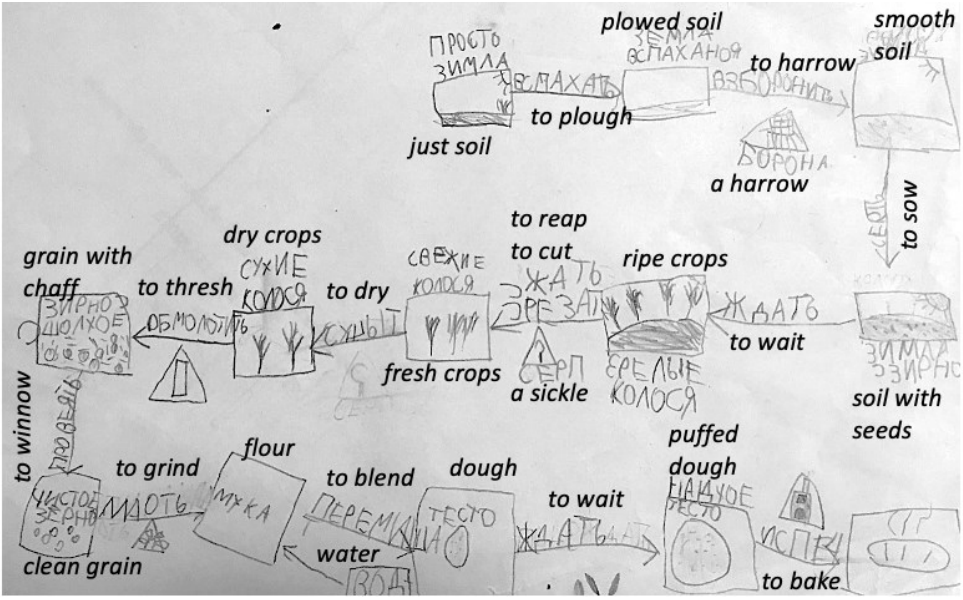

Fig. 1. The final technological chart on making bread. The work of the student V. (7 years old).

Students work within a "text-lab-model triad": they read the text fragment – reconstruct it on the technological chart – and test some of the operations within special "lab-lessons". Each transition between text and lab is mediated by modelling. The model also coordinates work of two partners - the technology chart demands pair work: one student is in charge of the products (final and intermediate) and the other – in charge of operations. The coordination of their work through choosing adequate instruments to achieve the desired characteristics of products is the framework for discussing the mechanisms behind the processes.

As the chart is to be drawn backwards, the story is examined in the same manner: from the last sentence "Then put in a hot oven" towards the start "First of all, we need to plow the land". The final technological chart after a month looks as on Fig.1.

The contradictions between "What it is" (model) and "What it seems" (everyday experience) are overcome by referring to text and experiment – thus, the technological chart guides student as he begins to rebuild his comprehension on a sound conceptual bases.

3 Results

The quality analyses of students' classroom activity, written tests, oral group discussions and teachers' feedback allows us to distinguish a number of "shifts" in students' actions, which indicate changes in the attitude to Natural Sciences and may reveal some aspects of psychological development. To illustrate the "shifts" we would provide a short example, extracted from a classroom discussion.

The task: "A modern combine harvester combines all the necessary work to "turn" crops into grain. List them".

1. Student N.: The combine cuts the wheat, turns it into flour and it takes away the chaff, and the combine ploughs the field…
2. Some students begin to object.
3. Student S.: No, look. The combine does not plough. The motor cultivator does.
4. Student N.: The combine can do many things. It can also plough!

…

5. Student A.: But look: It is said here [in the task]. A modern combine harvester combines all the necessary work to "turn" CROPS into GRAIN. And you say, combine digs earth?

6. Student S.: Yes, look at the scheme. From crops to grain. [Points the part of the technological chart].

7. Student R.: And you say, it "plows"! And "plow" is here, BEFORE "grain" and even before "crops".

In this small fragment we may observe that (the corresponding lines of the protocol are in parenthesis):

1. The students provide argumentation based on the model (5-7).
2. The students have the opportunity to debate over the matter itself (the discussion is not formal and perfunctory) and they do not need teacher guidance.
3. As they refer to the model, students can actually develop the solution of a complicated task, which could not be solved immediately (1), and eventually come up with the right answer.
4. Students refer to the text (5).

After the discussion students have to write down the answer. While they are writing it down, they repeatedly refer to the model. We have tried to introduce a special model of a sentence, so that students could plan their answer, but it appeared, that unless they refer to the model of the content itself, most of the students are unable to make up the answer even after they have discussed it.

4 Discussion

There are several "shifts", concerning initial competencies, that we have outlined, based on our pilot study.

1. Models are not an illustration, but a mental tool to mediate orientation. Visual models (the technological chart in particular) are acquired and applied consciously according to their orientation functions.
2. Reading competencies[†]. a) Comprehension of texts is mediated with models – thus, reading gains its purpose, as construction of the model directs reader's attention. b) Meanings of new unknown words are guessed from the context by students. Whereas in the beginning of the experiment students were confused with new terms (mostly concerning instruments and special operations) and asked the teacher "What does this mean?", in the end of the year they began to guess the meaning of most new words and asked "This word means … Am I right?"
3. Planning competencies. Students began to suggest, what experiments can be held to test this or that part of technological procedure, what can be done to support their argument (if the proofs cannot be extracted from the text description). Students shifted from the position "Let's do so and see what happens" to the conscious selection of the way to test their ideas in the class lab in order to get the anticipated result. Moreover, students began to keep track of the whole course structure: after a month each student could say, what the next lesson should be about. Thus, the consistent course structure based on the technologies that support human basic needs, and the shift of the teacher's role from leading to moderating, allow students to develop their learning initiative, which is one of the most important indicators of the sufficient psychological development in education [14, 15].

[†] In the beginning all of the students from our experiment class were able to read words, but only some of them could read whole texts fluently. Thus, we were able to observe the very formation of their reading skills during our lessons, though teaching students to read was not our immediate objective.

4. Communication competencies. As the protocol (above) shows, students learned to debate in a constructive way: for an argument they began to rely on the model, in particular, they shifted from a mere rejection and providing the right answer instead - to explaining, why exactly the classmate's answer was wrong: they could point, how the model would look like, based on the wrong answer, and how the technological process would look like, based on the wrong model.

5. Writing competencies. Students have significantly improved their own texts in both aspects: spelling and grammar. We assume, that the rich vocabulary related to the technological processes allowed students to examine some aspects of word etymology – and thus improve spelling. And at the same time the technological chart is a powerful tool for planning one's answer, as it helps the student to remember all the contexts, which he needs to explain in the text.

6. Future promotion in the domain. As students proceed to other technologies (making clothes or preparing lime mortar), they will also rely on technological charts, drawn from the final product backwards.

According to our hypothesis, the key to providing students with initial competencies is acquisition of the educational content while it is actually an orientation tool. The content thus is to be specially designed as a reconstruction of the situation of the concept origin in the history of human culture and certain symbolic means (models) are to be provided so that students can explicate their orientation and actually solve the problems together in symbolic external form. We conclude that the results of the current study support this hypothesis.

5 Conclusion

We believe, that our approach to introducing students to Natural Sciences through reconstruction of the initial scientific concepts' origin in the students' own activity is feasible. In Natural Sciences, this way, reconstruction concerns ancient technologies, which people developed and passed through generations as they strived to make things, they need, from nature materials. Though these archaic technologies seem to be outdated and thus unnecessary for a contemporary urban student to study, they are the gateway to understanding contemporary ones.

As the current study shows, the approach is quite promising in terms of scaffolding the initial competencies, such as comprehensive reading, composing texts, planning experiments, constructive debate and consistent argumentation and so on. Moreover, teaching primary school students allows to extend the processes of concepts' acquisition and competencies' formation and to examine it in detail. A thorough research on the psychological mechanisms of initial competencies' formation (especially modelling skills) is thus our next step.

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