Application of the "Fishbone" technology in the organization of independent work of students in higher mathematics

Irina G. Ustinova[1], Elena I. Podberezina[1], Elizaveta O. Shefer[3]

[1] National Research Tomsk Polytechnic University, Tomsk, Russia
{igu, pei}@tpu.ru, shefer_lizka@mail.ru

Abstract. Formation of a creative personality able to self-development, self-education, and innovative activity is the main objective of graduate education. In this regard, a special attention should be paid to the organization of independent work of students in a university educational process management. One of the most recognized types of independent work of students is a functional conspectus. "Fishbone" technology (a type of functional conspectus) is a method of cause-effect relationships structural analysis, which allows developing students' skills to work with information and their ability to formulate and to solve the problems. This paper deals with the application of this technology to the practical work on higher mathematics in order to increase the efficiency of the organization of independent work of students. Thus we have two objectives: first, to test the effectiveness of "Fishbone" technology in the organization of independent work, and second, to explore the possibility of using this technology in the higher mathematics university course. Comparative analysis of the test results of students who were trained with "Fishbone" technology application and without it demonstrates that its use can significantly increase the level of new information assimilation (in 19.8438%). Therefore, in future work we plan to consider applying other types of functional conspectus, such as insert, text markings, clusters, conceptual table and Bloom's chamomile to the course of higher mathematics in order to compare their efficiency in the organization of independent work of students and identify the most productive of them.

Keywords: Independent work of students, functional conspectus, "Fishbone" technology.

1 Introduction

At present time one's knowledge depreciates very quickly (about 15 – 20% per year). In other words, after 3 – 5 years a graduate loses much of the knowledge gained during the years of study. Under conditions of scientific and technical progress once acquired knowledge quickly becomes obsolete. Thus, the ability to acquire knowledge independently takes on great importance. Hence, the emphasis in education should be placed on the development of self-learning skill, development of the skill of creative application of acquired knowledge, as well as to the adaptation to the professional

activity in the modern world. Prominent authors note that the independent work of students "forms a readiness to self-education, creates a database of continuous education" under rapid updating knowledge condition [1 – 5].

Functional conspectus is one of the most important forms of independent work of students [6]. There are several varieties of functional conspectus. They are "Fishbone" technology, text marking, insert or efficient reading technology [7], clusters or bunches [8], conceptual table, and question chamomile or Bloom's chamomile [9]. Among all the varieties of functional conspectus we chose the "Fishbone" technology because it is the most promising for use in the higher mathematics studies. It allows students to divide the overall problem into a number of reasons and arguments. It also teaches to substantiate the assumptions, to visualize the relationship between cause and result, and to rank the factors according to their importance.

The term "Fishbone" [10 - 11] means "fish bone". The scheme was invented by Japanese Professor Kauro Ishikawa for the structural analysis of causality. The problem at hand is placed in the head of the fish skeleton (see. Fig. 1, left). The skeleton has the upper and lower bones. On the upper bones students fix the cause of the events. On the lower bones students write the facts, confirming the choice of causes. Notes on the bones should be brief. It should be the keywords, phrases, facts that reflect the crux of the matter. The conclusion on the problem should be placed in a tail part of the fish. Due to the fact that students may encounter difficulties in the preliminary finding of the causes and in the determining of the rate of its influence, the most effective way to use "Fishbone" scheme is use in the classroom, which are summarizes and systematizes the gained knowledge.

The goal of our work is the "Fishbone" technology application in higher mathematics practice in order to improve the organization of independent work of students. Research objectives are:

- To test the effectiveness of "Fishbone" technology in the organization of independent work of students;
- To explore the possibility of using this technology in the study of higher mathematics course.

We compare the test results of students who were trained with "Fishbone" technology application and without it to examine the effectiveness of the approach.

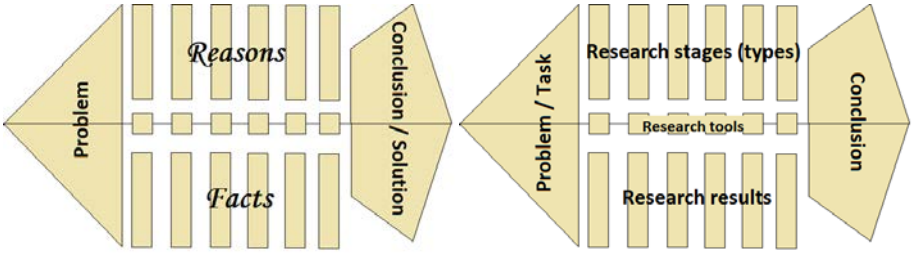

Fig. 1. "Fishbone" scheme (left); "Fishbone" scheme adaptation to mathematics (right)

2 "Fishbone" Technology Application in Mathematics

In mathematics "Fishbone" technology is convenient to use as a visual scheme of solutions of volumetric problems with exploratory nature. Research stages (types) are located in the upper bones of the fish. The spine consists of bones, where the mathematical tools of the study are located. The lower bones include research results (see Fig. 1, right).

Adapted to mathematical problems "Fishbone" scheme was successfully put into practice in the study of one of the most complex topics of higher mathematics "Indefinite integral" for the first year students of the Institute of Cybernetics and Institute of High Technologies of Tomsk Polytechnic University. It is well known from the experience of previous years, that the greatest difficulty for the students in solving problems of this topic was the choice of integration method. Many students recognized this fact, and found the solution easily after integration method was suggested to them. Therefore, the aim of the following treatment was integration method skill acquisition.

After all integration methods had been studied at the practical training, students were asked to complete a functional conspectus of four fish skeletons. In the heads of the skeletons the following problems were identified: "Integration by parts or a summarizing under the sign of the differential?", "Integration of trigonometric functions", "Integration of irrational functions" and "Different methods of integration." The upper bones of the skeletons "Research stages" included the indefinite integrals. On the lower bones of the skeleton "Research results" students have to write down the method of integration by which it was possible to find an appropriate replacement or specify substitution equation (in the case of irrational functions). On the bone of the spine they should substantiate their choice. The tail of the fish should contain a general conclusion for the integration.

Then the students received their test results and all four correctly completed functional schemes for self-error analysis. Students were also made aware of the fact that in a week they will re-do the test on indefinite integrals. Wherein, the best score will be taken into account. Consequently, they were interested in a thorough analysis of their own mistakes. The second test included different problems of the same difficulty level. Table 1 shows the results of both tests and functional conspectus. In the first column the student’s serial number is indicated. The second column contains the score of the first test, and the fourth contains the score of the second test. The result of functional conspectus is shown in the third column. The fifth and the sixth columns include the results of the first and second tests of the group, where the "Fishbone" technology was not implemented. The maximum score is 8 points. Some students have received more than 8 points due to additional tasks completion.

3 Data Analysis

Processing of the results of "Fishbone" technology application to practical training in higher mathematics was carried out using statistical methods [12]. Tables 2 – 3 sum-

Table 1. Tests results on "Indefinite integral" topic.

	With "Fishbone"			Without "Fishbone"	
Student's serial number	Test 1	Functional conspectus	Test 2	Test 1	Test 2
1	0	2.62	5.4	6	6.3
2	2	2.33	4.1	2	4
3	4	4.07	4.3	3	2.6
4	4	6.7	5.3	5.5	6.2
5	1	3.49	3.8	0.5	1.8
6	0.5	2.04	0.5	0	1.5
7	3	5.24	3.5	7	8
8	2	4.51	4.6	3	3.5
9	0.5	2.76	2.7	5	7
10	5	3.35	3.8	5.2	5
11	1.5	2.33	0	4	3.8
12	3.5	6.11	6.2	0	1
13	0	1.31	0	2	1.5
14	3	6.25	7.3	2	3
15	8	6.4	9.8	1	3
16	1.5	3.64	2.2	0	3
17	1.5	5.38	3.2	2	2.2
18	2.5	2.76	3.6	3.8	4.1
19	4.5	4.95	4.9	5	5.5
20	0	4.51	1.6	1	2.3
21	0	2.91	0	0	0.3
22	5.5	5.38	7	0.5	0.7
23	0	1.6	0	2	1.6
24	1	5.38	2	2	2.4
25	7	6.11	7	0.5	1
26	0	1.6	6.3	4	4.3
27	0	2.18	5.8	5	4.9
28	6	4.65	7	0.2	1.4
29	0	3.78	2.8	4	3.5
30	0	0.44	0	5	5.9
31	8	5.38	9.4	0	0.3
32	3	4.36	3.7	4	3
33	5	3.05	6.8	0	1
34	4	4.65	4.3	3.8	3.6
35	7.1	4.65	6	7	6.8
36	4	3.93	4.5	7.2	7.3
37	1,5	4.51	5.2	5.2	5.4
38	0	3.05	2	3.8	3.7
39	0.7	1.16	4.8	0.9	2.8
40	1.9	3.51	4.8	0.6	2.9

marize the main statistical characteristics of the test results. Here *xb* is the sample mean, which is equal to the sum of all points for the test divided by the number of students. The sample mean represents the average result of the test. *D* is the sample variance. It is equal to the sum of the squares of deviations of the students' scores from the sample mean, divided by the number of students. This value characterizes the dispersion of the individual scores of students with respect to the sample mean. σ is the sample standard deviation, which is equal to the square root of the sample variance. It is used to find the correlation coefficient. Sample correlation coefficient characterizes the presence of a linear relationship between the variables. If the sample correlation coefficient is equal to 1, the variables are linearly dependent. If it is equal to 0 there is no linear relationship between the variables, but there may be some other relationship. Ones on the diagonal in Table 3 mean that there is a linear relation between the same variables. The value of 0.73 indicates that the relationship is not linear between the scores of the first test and the second test. Value 0.938 proves a linear relationship between the control points for the first test and the second test. Thus, second test results of the students who used the "Fishbone" technology do not depend linearly on the results of the first test, while for the second group (without "Fishbone" technology implementation) this dependence is linear.

Table 2. Statistical Characteristic of the Tests' Results

Statistical characteristics	With "Fishbone"			Without "Fishbone"	
	Test 1	Func. consp.	Test 2	Test 1	Test 2
xb	2.5675	3.82575	4.155	3.293	3.813
D	5.833	2.484	6.163	5.235	4.124
σ	2.415	1.576	2.483	2.288	2.031

Table 3. Sample Correlation Coefficients of the Tests' Results

	With "Fishbone"			Without "Fishbone"	
	Test 1	Func. consp.	Test 2	Test 1	Test 2
Test 1	1	0.646	0.73	1	0.938
Func. consp.	0.646	1	0.571	-	-
Test 2	0.73	0.571	1	0.938	1

4 Conclusion

One of the main tasks of modern education is to create sustainable students motivation to learn. Another task is to search for new forms and tools of knowledge development through creative solutions.

This work describes one of the most important types of independent work of students. "Fishbone" technology allows to set the goals of learning, and to establish the ways of achieving these goals. The application of this technology in a higher mathematics practice was considered. On the basis of statistics it was found that the use of

this technology can significantly increase the level of new information assimilation (in 19.8438%). Therefore, in future work we plan to consider applying other types of functional conspectus, such as insert, text markings, clusters, conceptual table and Bloom's chamomile to the course of higher mathematics in order to compare their efficiency in the organization of independent work of students and identify the most productive of them.

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