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Connectedness of Physics and Chemistry Courses in the Group of Terms

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Abstract. The present article shows the results of comparing the connectedness between the high school courses of Physics and Chemistry. The calculation of connectedness has been conducted within a graph model of inter-subject links developed by Gnitetskaya Tatyana N. The inter-subject space of the Physics and Chemistry courses is based on this model. The quantitative characteristics of this model are used to establish the hierarchy of physical terms used in Chemistry, and chemical terms used in Physics for all combinations of the Physics and Chemistry courses under review. Quantitative values of the connectedness between the courses of Physics and Chemistry have been calculated; they are used as foundation for selecting the courses of Physics and Chemistry based on the position of connectedness.

Introduction

It is obvious that training of experts in Physics and Chemical technologies starts in high school and not in universities. The integrity and comprehensive structure of the subjects of Physics and Chemistry in high schools define the subsequent level of the students' ability to understand complicated chemical laws of the environment. It is crucial to establish connections with the subjects like Physics, Chemistry, Biology and others from the earliest stages of studying Chemistry. [1] Students will easier go over the barriers of new knowledge if they study the same natural phenomena in different subjects in connection with each other.

In other words, it is reasonable to define inter-subject links and emphasize them while studying the subjects of natural sciences. There are many research works describing inter-subject links at a qualitative level. We have developed a quantitative model of inter-subject links in the graph and informational representations. The basic principles of the models functioning have been described in the works [1, 8, 9].

Application of our model of inter-subject links to various pedagogical tasks has been described in many articles [articles - Scopus]. The present article provides a description of and offers a solution to a problem of combining the inter-subject content of high school textbooks on Chemistry and Physics based on the example of elementary school course of Chemistry described by three different authors and that of Physics described by three groups of authors.

Connectedness of Physics and Chemistry textbooks through a group of physical terms.

Calculation of the content connectedness of different Physics and Chemistry textbooks based on a graph model of inter-subject links is conducted in several stages. The first stage involves formation of direct Physics – Chemistry and reverse Chemistry – Physics inter-subject spaces for each pair of textbooks. In accordance with our definition of inter-subject links, the course of Physics is basic in the direct inter-subject space and is represented by a group of physical terms used in the content of the

Chemistry course which in its turn is connected. The structure of the connected course is shown on the top of the space table with inter-subject links. For example, refer to the direct inter-subject space of the Physics course by Purysheva N.C. (basic) and Chemistry by Gabriyelyan O.S. (connected) in Table1. Application of the quantitative approach suggested in the research work [9] to evaluation of inter-subject connectedness of different subjects allows to run a quantitative analysis of inter-subject links as well as to select the most content-connected textbooks on several sciences.

We have conducted a comparative analysis of the inter-subject content of Russian high school textbooks on Physics and Chemistry for 13-15 year-old pupils. Three Physics courses for 8-9th grades have been selected for analysis: 1) by A. V. Peryshkin [3], 2) by N. S. Purysheva and N. E. Vazheyevskaya [4] and 3) S.V. Gromov [7], and three courses of Chemistry for 8-9th grades: by O. S. Gabriyelyan [5], 2) by G. E. Rudzitis and F. G. Feldman [6] and 3) by R.G. Ivanova set forth in the corresponding textbooks. The selected textbooks are included into the Federal Textbook List recommended by the Ministry of Education and Science of the Russian Federation for use in teaching in secondary-education institutions in the inter-subject content of nine combinations of these courses in the group of physical courses used in Chemistry. The spaces represent four arrays of inter-subject links discovered between the structural elements of the Physics course for 7-9th grades and Chemistry for 8-9th grades: 1) Chemistry by O.S. Gabriyelyan and Physics by A.V. Peryshkin; 2) Chemistry by O.S. Gabriyelyan and Physics by N.S. Purysheva, N.E. Vazheyevskaya; 3) Chemistry by G.E. Rudzitis, F.G. Feldman and Physics by A.V. Peryshkin; 4) Chemistry by G.E.Rudzitis, F.G. Feldman and Physics by N.S. Purysheva and N.E. Vazheyevskaya (see, for example, Table 1).

Table 1

Space of inter-subject content of the Physics course for 7-9th grades by N.S. Purysheva, N.E. Vazheyevskaya and connected course of Chemistry for 8-9th grades by O.S. Gabriyelyan

	Structure of Chemistry course / Group of physical terms	Atoms of chemical elements	Compounds of chemical elements	Speed of chemical reactions. Chemical balance.	Solutions. Ion exchange reactions.	Introduction. General characteristic of chemical elements	Metals	Non-metals of I -VII A subgroups	Non-metals of IV-V A subgroups	Organic compounds	Relative max. Length L	Relative link force C
		1	2	3	4	5	6	7	8	9		
1	Atom	♦	♦		♦	♦	♦	♦	♦	♦	1,00	1,00
2	Heat (quantity of heat)		♦	♦	♦		♦	♦	♦	♦	1,00	0,86
3	Temperature	♦	♦	♦	♦	♦	♦		♦	♦	1,00	0,86
4	Molecule	♦	♦	♦	♦		♦	♦	♦	♦	1,00	0,86
5	Electron	♦	♦		♦	♦	♦	♦	♦	♦	1,00	0,81
6	Aggregate state	♦	♦		♦		♦	♦	♦	♦	1,00	0,78
7	Pressure		♦	♦	♦				♦	♦	1,00	0,63
8	Density	♦	♦			♦	♦	♦	♦	♦	1,00	0,61
9	Atomic mass (molecular)	♦				♦			♦	♦	1,00	0,38
10	Energy	♦					♦	♦	♦	♦	1,00	0,31
11	Light							♦	♦	♦	1,00	0,23
15	α- particles	♦									1,00	0,15
16	β – rays (steam of electrons)	♦									1,00	0,15
17	γ – rays (em. interaction)	♦									1,00	0,15
13	Speed of light	♦									1,00	0,15
50	Charge	♦	♦								0,33	0,33
55	Heat effect		♦		♦						0,33	0,33
104	Nuclear energy	♦									0,11	0,11

Chemistry becomes a basic course in the reverse inter-subject space. Qualitative characteristics of the length and force of connection in the list of chemical and physical terms help to establish a hierarchical order of priority. Knowing the measure of significance, we can identify the fundamental core of Physics in the course of Chemistry in the direct inter-subject space, and vice versa, a fundamental core of Chemistry in the course of Physics in the reverse inter-subject space.

This distribution of fundamental physical terms will help define a conceptual framework of the reviewed course of Chemistry.

The connectedness of two courses has been calculated through a qualitative feature between the force of connection $C^{(ex)}$ of two Physics and Chemistry courses in the group of physical terms by the following formula

$$C^{(ex)} = \frac{F^{(ex)}(EG_{\mu}^{\nu})}{N} \quad (1)$$

where N - is a number of structure elements of the connected course; F - is a sum of all forces in the group of terms.

Table 2
Connectedness of the courses of Physics and Chemistry
through a group of physical terms used in the courses of Chemistry.

Course of Chemistry / Course of Physics	O.S. Gabriyelyan	G.E. Rudzitis, F.G. Feldman	R.G. Ivanova
	Connectedness of the textbooks on Physics and Chemistry		
A.V. Peryshkin	0,40	0,43	0,31
N.S. Purysheva, N.E. Vazheyevaksya	0,45	0,39	0,30
S.V. Gromov and N.A. Rodina	0,36	0,38	0,38

In fact, the parameter of connectedness between two courses calculated in the group of terms is a sum of connectedness values determined for physical terms introduced into the reviewed course of Physics and used in the analyzed course of Chemistry.

The results of connectedness calculations for different combinations of courses are provided in Table 2, which shows that a prevailing connectedness *C=0.45*has been established between the course of Physics by N.S. Purysheva and N.E. Vazheyevskaya for 7-9th grades, and the course of Chemistry by O.S. Gabriyelyan for 8-9th grades. The course by A.V. Peryshkin has a greater degree of connectedness with the course of Chemistry by O.S. Gabriyelyan *C=0.43.* The course of Physics by S.V. Gromov and N.A. Rodina is connected with the course of Chemistry by R.G. Ivanova more than with other courses of Chemistry *C=0.38.*

Connectedness of the textbooks on Chemistry and Physics in the group of chemical terms.

The reverse task, i.e. the connectedness of the Chemistry course and Physics course through chemical terms introduced in the given Chemistry course and used in the given Physics course was solved based on the content of the same courses. As well as in the previous case, four inter-subject spaces of the courses pairs were built. The difference is that all chemical terms introduced in the chosen Chemistry courses were selected, and their usage was traced in the Physics textbooks of the course under review.

The results of solving the reverse task are shown in table 3. It is clear that optimal connectedness in a group of chemical terms *C=0.26* was established between the Chemistry course by R.G. Ivanova for 8-9th grades and the Physics course by S.V. Gromov and N.A. Rodina for 7-9th grades.

Table 3
Connectedness of the courses of Chemistry and Physics
through a group of chemical terms used in the courses of Chemistry.

Course of Physics / Course of Chemistry	A.V. Peryshkin	N.S. Purysheva N.E. Vazheyevskaya	S.V. Gromov, N.A. Rodina
	Connectedness of the courses of Physics and Chemistry		
O.S. Gabriyelyan	0, 21	0,22	0,18
G.E. Rudzitis, F.G. Feldman	0,21	0,22	0,24
R.G. Ivanova	0,17	0,20	0,26

Therefore, based on the data obtained while studying Physics in 7-9th grades based on N.C. Purysheva, N.S. Vazheyevskaya textbook it is recommended that pupils start studying Chemistry in 8-9th grades using both textbooks by O.S. Gabrieylyan and G.E. Rudzitis with the preference given to the Chemistry textbook by O.S. Gabriyelyan. If Physics is studied based on A.B. Peryshkin's textbook, then O.S. Gabriyelyan's textbook on Chemistry should be also selected since the connectedness in both directions has the maximum values for this pair of textbooks.

The course of Physics for 7-9th grades by N.S. Purysheva and N.E. Vazheyevskaya has one advantage: the content of the 7th grade textbook almost never use chemical terms and names of chemical substances, which is very logical since high school pupils begin to study Chemistry only in the 8th grade. The section called *Density of Matter*, which introduces the names of several chemical substances and their density values, is the only exception. However, it is quite reasonable and complies with the logic of the textbook structure.

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