Evaluation of connectedness between the University courses of Physics and Chemistry basing on the graph model of inter-subject links

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Abstract. An application of the graph model of inter-subject links to University courses of Physics and Chemistry is presented in this article. A part of inter-subject space with directions of inter-subject links from Physics to Chemistry in the group of physical concepts has been shown. The graph model of inter-subject links includes quantitative indicators. Its numerical values are given in the article. The degree of connectedness between the data of Physics and Chemistry courses is discussed for the courses considered. The effect of the courses placement within a curriculum on the value of their connectedness is shown. The placement of courses within a curriculum can provide the study of the courses at the same time or consecutive study, when one course precedes another.

1. Introduction
Currently, there is need for a new engineering profession. The specialists owning it perform the functions of non-technical nature. They are engineers-ecologists, engineers-managers in various fields, and others. Training of such specialists is distinguished by the presence of natural sciences in the curriculum, which must include Physics and Chemistry as obligatory disciplines. At the same time, differentiation of training courses can lead to a distortion of the students’ ideas about the surrounding World, the main feature of which is its internal unity. It is possible to establish interdisciplinary connection with the help of the graph model for interdisciplinary connection, proposed by T. Gnitetskaya [1]. Revealing of the same interdisciplinary relationship in training courses will allow to establish the picture of interconnectedness of these courses content and therefore may contribute to the formation of academic content of the courses in Physics and Chemistry, which would meet the requirements of integrity.

2 Graph Model of interdisciplinary connections
Quantitative evaluation of connectedness in Physics and Chemistry courses was performed using a graph model of interdisciplinary connections, as described in this work [1]. Graph model has allowed performing a comparative analysis of content connectedness of training courses in Physics and Chemistry used in the preparation of engineers-managers.
The model assumes construction of interdisciplinary space for the courses under review. Description of its content and procedure of forming are shown below. We had to form two interdisciplinary spaces of Physics [2] and Chemistry [3] courses, which differ from each other by the time of studying the Physics course. In the first case (fig.1) the courses in Chemistry and Physics are studied simultaneously, in the second case the study of Physics course precedes Chemistry course (fig.2). Within the framework of the used graph model interdisciplinary connections are realized through the connection object, which is one of any element of knowledge (concepts, theories, laws, etc.) in Physics course. We examined a group of physical concepts. The connection has the direction from Physics to Chemistry and is installed between the whole Physics course (basic course) and the elements of the structure of Chemistry course (related course).

Interdisciplinary space of Physics and Chemistry courses represents a table in which structural elements of Chemistry course are distributed horizontally, and physical concepts - vertically. The cells at the intersection of rows and columns are marked if the physical concepts are used in this element of the Chemistry course’ structure. For example, physical and chemical space is constructed as follows: a diamond icon is placed in the cell that corresponds to the structural element of Chemistry course, which uses this physical concept. The cell is painted if this structural element of related Chemistry course coincides with the moment of formation of physical concept under review in basic Physics course. Thus, there are four types of cells - with diamond, shaded, shaded with diamond, and empty cells. For example, the concept of the mass is studied in Physics course prior to its use in the course of Chemistry - the first cell is painted. Diamonds are located in those cells (1, 2, 3, 6, 7, 9, 10, 11, 12, 13, 14, 15, 17, 20, 22), where the concept of mass is used in the course of Chemistry. Within the framework of the theory it can be calculated with the following quantitative characteristics of interdisciplinary connections.

Relative maximum length of interdisciplinary connection:

\[ L^{(ex)}(EG_{\mu}) = \frac{i_{\text{max}} - k_{\mu} + 1}{N} \]  

(1)

where \( i_{\text{max}} \) – is the number of structural elements, where the connection is terminated; \( k_{\mu} \) – is the root node or the elements’ number, where a physical concept is used in Chemistry course for the first time; \( N \) - the number of the structural elements in Chemistry course.

For example, for the concept of the mass the relative maximum connection length is equal to 1.00, and for the concept of viscosity- 0.91. The relative strength of ILC

\[ C^{(ex)}(EG_{\mu}) = \frac{F^{(ex)}(EG_{\mu})}{N} \]  

(2)

Where, 

\[ F^{(ex)}(EG_{\mu}) = \sum f^{(ex)}_{i}(EG_{\mu}) \]

, where,

\[ f^{(ex)}_{i}(EG_{\mu}) = \frac{(i-k_{\mu}+1) - R^{(ex)}_{k_{\mu}i}(EG_{\mu})}{(i-k_{\mu}+1)} \]

Here, \( R \) - the number of unmarked cells.

The relative strength of connection is established between the elements of the structure through any concept. For example, for the concept of mass the relative connection strength is equal to 0.61 and 0.10 for the concept of viscosity.

Knowledge of the values of these characteristics of interdisciplinary connections for each element of knowledge in a group of concepts [1] allows building physical concepts according to their significance in the course of Chemistry. Where the fundamental interdisciplinary core of Physics and Chemistry will include physical concepts, which values of relative maximum lengths of interdisciplinary connections are \( L = 1 \), and the values of the relative strengths of connection belong to the interval 1.00 \( \leq C \leq 0.73 \) [4].
Fundamental concepts are those that are used in each section of related course. In Table 2 such fundamental concepts include: atom, energy, temperature, molecule, and electron. Where $R$ – is the number of unmarked cells in the table for a given concept. For example, for the concept of the mass unmarked cells are the cells 4, 5, 8, 16, 18, 19, 21.

3 Connectedness of courses in Physics and Chemistry
Calculation of the quantitative characteristics - length and strength of the connection - made it possible to calculate the connectedness of courses in Physics and Chemistry. The calculation results are summarized in Table 1.

**Table 1.** Connectedness of courses in Physics by authors A. Remizov, A. Potapenko and Chemistry by N. Glinka on a group of physical concepts in the direction of interdisciplinary connections from Physics to Chemistry

| Related course – Chemistry, N. Glinka | Connectedness of training courses for a group of concepts, $C$ | Full strength of connection, $F$ |
|-----------------------------------|-------------------------------------------------|------------------|
| Physics course precedes Chemistry course | 0.14 | 35.09 |
| Physics course is studied simultaneously with the course of Chemistry | 0.12 | 31.50 |

Typically, engineers’ courses in Physics and Chemistry are given simultaneously from the second semester of the 1-st training course at the university. In this case, the connectedness of Physics and Chemistry courses for a group of physical concepts is 0.12.

**Table 2.** The space of interdisciplinary content of the basic course in Physics and related Chemistry course by authors [2, 3], in the case where courses in Physics and Chemistry are studied simultaneously

| Physical notions | Atomic-molecular theory | Periodic law of Mendeleev | Structure of the atom | Chemical link | Regularities of the solid, liquid | Water, solutions | Electrolyte solutions | Disperse systems, colloids | Hydrogen | Halogens | V A group | IV A group | Properties of metals, Alloys | Complex compounds | The 2nd group of the PS | The 3rd group of the PS | Properties of the PS VIII group | Relat. max. length $L$ | Relat. max. strength $C$ |
|-----------------|------------------------|--------------------------|----------------------|-------------|---------------------------------|----------------|----------------------|--------------------------|----------|---------|-----------|-------------|--------------------------|-------------------|----------------------|----------------------|--------------------------|----------------|----------------|
| 1 Atom | | | | | | | | | | | | | | | | | 1.00 | 1.00 |
| 2 Energy | | | | | | | | | | | | | | | | | 1.00 | 1.00 |
| 3 Temperature | | | | | | | | | | | | | | | | | 1.00 | 0.88 |
| 4 Molecule | | | | | | | | | | | | | | | | | 1.00 | 0.85 |
| 5 Electron | | | | | | | | | | | | | | | | | 1.00 | 0.75 |
| 6 Mass | | | | | | | | | | | | | | | | | 1.00 | 0.61 |
| 18 Spectrum | | | | | | | | | | | | | | | | | 0.91 | 0.13 |
| 254 Deuterons | | | | | | | | | | | | | | | | | 0.05 | 0.05 |
Also, a fragment of the table shown in Table 2 shows that the number of physical concepts is large enough – 254. Frequently, students face the challenge of not understanding of some physical concepts since in the course of Chemistry they are used in the beginning of the study and in Physics course these concepts will be studied only at the end of the study. These are such concepts as α-rays, infrared rays and many others.

### Table 3. The space of interdisciplinary content of the basic course in Physics and related Chemistry course authors [2, 3], in the case where the Physics course precedes the study of Chemistry course.

| Element of chemistry course structure | Physical notions | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 |
|--------------------------------------|-----------------|---|---|---|---|---|---|---|---|---|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| Atomic-molecular theory              | Periodic law of Mendeleev |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    | 1.00 | 1.00 |
| Structure of the atom                | Chemical link, structure of molecule |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    | 1.00 | 0.91 |
| The state of the solid, liquid      | Electrolyte solutions |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    | 1.00 | 0.91 |
| Water, solutions                     | Red-Ox reactions, Electrochem. |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    | 1.00 | 0.90 |
| Disperse systems, coloids           | VI A group       |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    | 1.00 | 0.73 |
| Litho, H2                            | V A group        |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    | 1.00 | 0.61 |
| Properties of metals, Alloys        | The 1A group of the PS |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    | :    | :    | :    |
| Complex compounds                   | The 2A group of the PS |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    | 0.91 | 0.21 |
| Disperse systems, coloids           | The 3A group of the PS |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    | :    | :    | :    |
| report type                          | VIII group       |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    | 0.05 | 0.05 |

For comparison of the results the connectivity of courses in Physics and Chemistry was calculated, as well as a full-strength connection for the case when the study of the Physics course is preceded by the study of Chemistry course. The value of connectedness in this case will be 0.14, and the value of full connection strength increases up to 35.09.

### Conclusions

Thus, in forming-up both the content of reduced natural science courses and the process of teaching these courses it is necessary to analyze their connectedness level and to conduct suitable adequate course content optimization. It is evident that increasing the value of connectedness of courses will increase the level of assimilation of knowledge by the students that in turn leads to the formation of complete ideas about the World. Therefore, we can recommend studying Physics course before learning Chemistry course while preparing students, future engineers-managers.

### References

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