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Modeling of Interdisciplinary Connections in Science Courses

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Abstract. Graph model of interdisciplinary connections, and method of calculation quantitative parameters of model have described. The application of quantitative method to content of physics and mathematics has already done in this paper. The hierarchy of mathematical concepts used by the general physics course is established co according to two parameters - the bond strength (frequency of use) and the bond length (duration of use).

1. Introduction

It is very important today make a systems of inter- and intra- disciplinary connections as a basis of training course before the moment when the content of this course is began to create. These systems allow to decide some problems: 1) the intra-disciplinary connections' system helps us to understand which part of training content is actual to include into the training course but which part of training content is not so important and could be deleted; 2) we could see a level of connectedness between disciplines and optimize their content For example, concepts of derivative, integral and etc. are the main concepts in physics' description of natural phenomena, furthermore these mathematical concepts have physical meaning. The derivative - as the speed of functions' changing and an integral - as a length of way or limit of sum of lengths of an elementary segments, which the whole length of way were divided. This article is aimed to describe a graph model of inter- disciplinary connections [1] and its application to the optimization problem of the content of physics and mathematics for first years of physics learning at the university.

2. Graph Model of Interdisciplinary university Connection

2.1. Definition of interdisciplinary connection

Currently known definitions of the interdisciplinary connection, there are more than 30, represent any functions or properties of connection only qualitatively.

This approach based on suggested definition of interdisciplinary connections enable not only vividly represent these connections in disciplines but to evaluate them quantitatively [1].

According to definition illustrated above the interdisciplinary connection is understood as a structure of elements of the pedagogical system which connects the elements of the structure of interdisciplinary content of education and consists of: 1) connection object – any element of knowledge, skills and abilities belonged to a basic subject and used in the connected one (at least, in two elements of its structure); 2) connection channel – one or more elements of the educational technology, equal to subjects between a connection is established. A direction of interdisciplinary connection is given by a choice of the basic subject – from the basic subject to the connected one. The same connection cannot

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have a direct and reverse direction. Even with the same connection object a connection channel from subject A to subject B does not coincide with a connection channel from B to A. An illustration of the definition is given in Fig. 1.

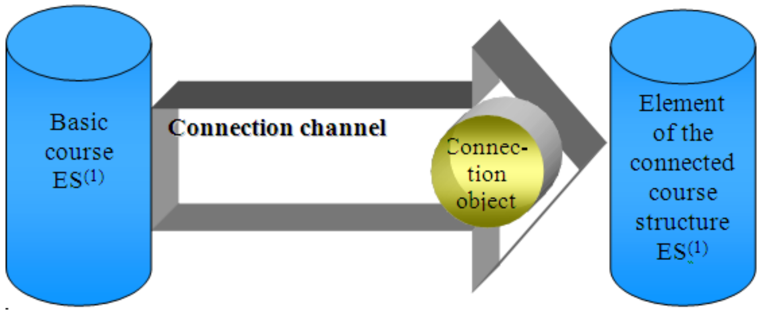

Figure 1. Illustration of interdisciplinary connection definition

The given interdisciplinary connection definition differs substantially from the already existing in the interpretation of the connection as an object responsible for transfer of teaching information, besides, connection structure is determined. This allows presenting the interdisciplinary connection as graph and information models that make it possible to carry out a quantitative assessment of interdisciplinary connections.

2.2. Model

Let us describe the graph model of the interdisciplinary connection by example of the interdisciplinary space created by the courses of General Physics [2] - hereinafter referred to as physics, and Mathematic Analysis [3] - hereinafter referred to as mathematics, which are obligatory to learn for the students majoring in natural sciences in their first university years. In this case mathematics is a **basic** discipline, and physics is a **connected** one. Then the **objects of the connection** are knowledge elements (mathematical notions, theorems, axioms), skills and abilities that are part of mathematics and used in physics. Interdisciplinary connections are established between the whole mathematic course (basic) and any element of physic course (connected) structure.

Let us unite, according to [1], mathematical notions, theorems, axioms, skills and abilities used in the mathematics into five relevant groups and connect the set of physics' structure elements to the set of mathematics' group elements. Let us mark every group element as $\{EG_{\mu}^{\nu}\}$, where μ is the number of group element, ν is the number of a group. For example, the derivative could be represented as $\{EG_1^6\}$. Crossing of structure elements set with any of the set of knowledge elements divides any structure elements set into cells (see table 1). We will consider the cell filled (marked with a rhombus) if a content of physics structure element uses this mathematical notion of the set of such cells, which are the nods of the interdisciplinary connection and represent the space of the interdisciplinary contents of the physics and mathematics education.

The interdisciplinary connections implemented through the connection object, may be presented as oriented marked graphs. Each graph is a tree having its beginning in a marked (base) node $J_k(EG_{\mu}^{\nu})$, which is the same for all interdisciplinary connections implemented through the connection object. k is the number of physics' element structure where graph began. The graphs end in the nods (leaf nodes) of the subset, which are marked in case the connection object is used in the content of i th structure element. Our terminology coincides with that used in the book [4]. Thus, a knowledge element of the mathematics may be used in the physics course prior to learning it in the mathematics, concur in time of learning, and be learned after it was introduced in physics. The time of learning mathematical notion in the mathematics is registered by filling the mth cell of the physics structure element which learning falls within the same time interval, this nod is marked $J_{m_\mu}(EG_\mu^\nu)$. For derivative example, $J_{m_{6=3}}(EG_6^1)$ (see table 1).

Methodological approaches and techniques used by physics and math teachers within the time allotted according to curriculum, significantly distinguish and this determines a nonequivalence of connection channels and, finally connections themselves. There is a good reason to introduce a notion of capacity [5] of interdisciplinary connections, mentioned nonequivalence of teaching information transfer from one structural element to another. Capacity of a connection channel shall be defined by the speed (maximal) of teaching information transmission (C), i.e. amount of the teaching information (S) transferred per time unit (T): $C = S/T$ [bits/sec].

As students in a learning process carry out acquisition and application of the interdisciplinary knowledge, abilities and skills, the interdisciplinary connection is formed through time, from one element of structure to another. Therefore the capacity of interdisciplinary connection is function of time or function of not marked nod' number: $P_{i\,m}^{(ex)}(t) = p_{i\,m}^{(ex)}(J_k(EG_\mu^\nu))$.

The described graph model of the interdisciplinary connections allows introducing their quantitative characteristics.

If T_k takes as the duration of study of single structural element, numbered *k,* then the duration of the i [th] interdisciplinary connection will be: $(\tau_i(EG_\mu^\nu) = \sum_{k=k_\mu}^{i} T_k$.

For example: duration of interdisciplinary connections established between mathematics and physics through derivative is $\tau_{20}(EG_6^1) = \sum_{k=1}^{20} T_k$.

This duration may be considered as an indicator of connection length or value of the connected oriented graph radius only within the scope of this task

$$L_i^{(ex)}(EG_\mu^\nu) = \sum_{k=k_\mu}^{i} p_{k_\mu i}^{(ex)}(J_k\,(EG_\mu^\nu))T_k.$$

Presence of fractures, i.e. such elements of physics structure in which a mathematical notion is not used, weakens the interdisciplinary connection. Therefore, the interdisciplinary connection strength may be an indicator of internal interconnection level: $f_i^{(ex)}(EG_\mu^\nu) = \frac{\tilde{L}_i^{(ex)}(EG_\mu^\nu)}{L_i^{(ex)}(EG_\mu^\nu)}$,

where effective continuous length of interdisciplinary connection is:

$$\tilde{L}_i^{(ex)}(EG_\mu^\nu) = \sum_{k=k_\mu}^{i} p_{k_\mu i}^{(ex)}\left(J_k(EG_\mu^\nu)\right)T_k - R_{k_\mu i}^{(ex)}(EG_\mu^\nu)$$

and length of fractures is: $R_{k_\mu\,i}^{(ex)}(EG_\mu^\nu) = \sum_k p_{k_\mu\,i}^{(ex)}\,(J_k(EG_\mu^\nu))T_k$

3. Findings

The table 1 shows the fragment of the set of mathematical notions crossing with the set of structural elements of the physics course. The structure of the chosen general physics course contains twenty structural elements which sequence is deemed traditional. Again, the application of this mathematical notion in the physics structural element is registered by the presence of a rhombus in the cell of their crossing. The graphs in the table 1 are presented for the connections established through the connection object – Derivative. It may be seen from the table that the notion of the derivative was first introduced by the physics teacher in the first structural element "Kinematics", while a grounded definition of the derivative appeared in mathematics much later and concurs with the time of studying structural physics element "Conservation law". If a mathematical notion was formed out in physics, then we consider that it was used in physics for the first time, which is why the base node of graphs of the derivative notion is referred to the first structural element. Graphs for all other mathematical notions are formed based on the same principle. Absence of cycles in the graphs depends on the learning process logics. If the interdisciplinary information is used in several elements of the connected element structure, it is impossible to transfer this information to the last of them escaping the intermediate ones. Absolute characteristics depend on the amount of structural elements in a connected discipline but it is inconvenient to use. In this connection, relative characteristics of the interdisciplinary connections have been introduced as presented in the table – relative maximal length *L* and relative connection strength *C*.

Table 1. Distribution of mathematical notions in the traditional general physics course structure (fragment)

Element of structure of physics	Mechanics						Molecular physics and thermodynamics				Electromagnetics					Waves			Atomic and nuclear physics		Relative maximal length	Connection relative strength
	Kinematics	Dynamics	Conservation laws	Rigid body dynamics	Oscillation	Universal gravitation	Thermodynamics	Statistic laws	Gases and liquids	Solids	Static electrical field: In vacuum	Static electrical field: In matter	Static magnetic field: In vacuum	Static magnetic field: In matter	Quasi-steady electromagnetic field	Elastic waves	Electro-magnetic interaction: In vacuum	Electro-magnetic interaction: In matter	Atomic physics	Elementary particle physics		
Mathematical notions	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	L	C
1 Function	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	1,00	1,00
2 Constant	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	1,00	1,00
3 Differential	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	1,00	1,00
: :																						
6 Derivative	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆			◆	◆	◆	◆	◆	◆	◆	◆	1,00	0,87
: :																						
24 Definite integral	◆		◆	◆	◆	◆	◆	◆			◆	◆	◆		◆			◆	◆		0,95	0,51
: :																						
89 Fourier integral																		◆			0,05	0,05

Of course the quantitative apparatus of this model was significantly simplified by bringing it to a homogeneous form. The structures which learning duration in respect to each element is identical and equal to one are accepted as "homogenous in duration**".**Formulae, methods of calculations and whole mathematical apparatus are given in details in the book [1].

4. Conclusion

Calculation of quantitative characteristics enables to establish the hierarchy of mathematical notions by their significance level in physics course. As Table 1 shows, such mathematical notions are ranked by connection length at first, and then by connection strength. The hierarchy formation permits us to abstract a fundamental kernel in the mathematical notion set, upon which we should rely when developing physics and mathematics courses for physics learning. Thus, the suggested approach based on a graph model of interdisciplinary connections supplemented by quantitative characteristics may be recommended for selection, structuring, systematization and optimization of the physical and mathematical content, which should precede the development of physics and mathematics courses in distance learning.

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