# Problems of Designing Polylingual Ontology OntoMath$^{Edu}$

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**Abstract.** We present the polylingual problems encountered in the design of the educational ontology OntoMathEdu and describe the developed solutions. Some of these problems and their solutions became the basis for the development of new solutions in the design of the entire ontology. The content of mathematical education, approaches to the definition of a number of mathematical concepts both in general and at different levels of instruction are different. Therefore, there are differences between the sets of concepts of ontology as a whole and its educational projections for use in Russian-language, English-language, and Tatar-language learning environments. It is planned to use the OntoMathEdu ontology with projections for various language learning environments in teaching digital systems. In particular, for teaching mathematics in English to foreign students, helping Russian schoolchildren and students to learn English.

**Keywords:** Polylingual education · Mathematical terms · Educational ontology · OntoMathEdu · Plane geometry

## 1 Introduction

Modern educational platforms offer many different MOOC courses in school and university disciplines for different language audiences. At the same time, most of the courses are tied to one language of instruction, and translation into the student's language occurs automatically (literally) using a browser. For example, on the Russian version of the Khan Academy website, there is only one course in mathematics, and the terms have an unusual translation into Russian. The English version of the site contains several dozen courses for various levels of education. The mission of the developers is to provide free education around the world. However, it is important to understand that the terms of various scientific fields require special translation; the terms of education must correspond to the curricula and traditions of the countries. Therefore, the problem of correct translation is especially relevant for MOOC, SPOC courses to expand the audience. The time has come when it is necessary to create polylingual courses that will look adequate in different languages, the terminology in them will correspond to the language of the student.


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Nevertheless, the problem of the effectiveness of these resources remains urgent due to the lack of general didactic principles for their organization and application in the educational process at different stages of education. A modern electronic course requires the availability of intelligent databases based on subject ontologies, the introduction of recommendation systems that can build individual learning paths and offer additional educational information based on the educational levels of students.

For the first time, the educational mathematical ontology OntoMathEdu is created at the Kazan Federal University by the team of mathematicians, specialists in the field of ontologies and mathematical education in three languages: English, Russian and Tatar [1]. Ontology was designed on the basis of concepts used in Russian and English-language school textbooks of geometry, and OntoMathEdu is presented in three languages: Russian, English [2] and Tatar [3]. Textbooks in the Tatar language are translated from Russian. The Tatar language is the national language of the Republic of Tatarstan and is used in teaching schoolchildren. The choice of English is also due to the compulsory study of a foreign language in Russian schools. The projection of an ontology in English is capable of performing a double function: to teach mathematics foreign students in English and to help Russian schoolchildren and students in learning a foreign language, to deepen knowledge of the subject in accordance with the distinctive features of educational systems.

The feature of the created ontology is the requirements for its content. On the one hand, ontology projections in all three languages must interact with each other. On the other hand, each of them should be a complete product, thanks to which one can teach mathematics. As a result of this approach, problems arise in translating certain terms and terminological structures due to the difference between Russian and foreign (English) educational programs, and the dependence of the methods for defining terms on existing cultural realities. Subsequently, the identified translation problems affect the design of the ontology as a whole.

## 2 Overview of Existing Ontologies in the Educational Field

At the moment, formalization of subject areas is an urgent problem of digitalization of education. In world scientific practice, there are various types of ontologies; the most extensive area is represented by upper-level ontologies (metaontologies), which describe concepts and relations that are independent of a specific subject area. Examples of such ontologies are DC (Dublin Core), BIBO (The Bibliographic Ontology), AIISO (the Academic Institution Internal Structure Ontology), SKOS (Simple Knowledge Organization System) and etc. [4].

Subject ontologies contain dictionaries of terms used in metaontologies and describe the concepts of a particular subject area and the tasks it solves. In the field of mathematics, ontologies such as Mocassin, ScienceWISE, OntoMathPro [5]. Ontologies in the field of education informatization are also developing: ontology “E-learning” [4], ontology of educational standards [6], ontology of university courses [7], ontology of training programs and automatic testing of knowledge in business informatics [8].

Among the ontologies that have been developed to date, there are no mathematical high school ontologies containing a full range of terms and theorems, the task of which is their further use in digital learning environments for schoolchildren. In particular, the use of markup of educational materials, test generation, automatic recommendation of educational materials in accordance with the curriculum [5]. The developed ontology performs not only a reference function, but also a teaching one – the primary task of the OntoMathEdu ontology is to use the ontology in educational electronic resources.

## 3 Polylingual Problems of Designing Ontology OntoMathEdu

The main problems of OntoMathEdu ontology design are related to the formalization of geometric concepts, the relations between them, the construction of full-fledged language projections of educational ontologies. To do this, the following steps are required:

1. Development of general requirements for ontology: the formation of a base of materials, sources, textbooks, the definition of the form, content and characteristics of the concepts presented in three languages.
2. Selection of the maximum number of geometric concepts covering educational subjects in three languages.
3. The construction of selected geometric concepts in a joint hierarchy.
4. Creating different kinds of relationships between concepts.
5. Filling the content of the selected concepts and relationships (definitions, images, links to external resources, etc.).
6. Ensuring the relationship between ontology projections in different languages, without violating their educational essence, integrity and independence.

When implementing the above steps, design problems arose with the ontology polylingualism. Two levels of problems are highlighted. The first level is associated with a different understanding and the presence of mathematical terms and an ambiguous approach to their definition in various educational systems. The second level has problems of a linguistic nature (ways of translating terms and definitions), since it is impossible to carry out literal translation, while preserving the systematic educational nature of the ontology in Russian or English.

### 3.1 Development of General Requirements for Ontology

At this stage of the development of the OntoMathEdu ontology, the following categories are allocated for each mathematical concept (Table 1):

**Table 1.** Categories of mathematical concepts in ontology OntoMathEdu

| Ontology projection<br>Category of mathematical concept | Russian | English | Tatar |
|---|---|---|---|
| Ontological term | ✓ | ✓ | ✓ |
| School term | ✓ | ✓ | ✓ |
| Wiki article link | ✓ | ✓ | |
| Link to an educational resource | ✓ | ✓ | |
| Educational level | ✓ | ✓ | |

At the same time, ontological terms perform the function of structuring the ontology, they may coincide with the school term, have a school analogue, or the school term may be absent for a given ontological term (Table 2).

**Table 2.** Examples of mathematical term in ontology OntoMathEdu

| | Ontological term | School term |
|---|---|---|
| Ontological and school terms coincide | Треугольник (Treugol'nik) | Треугольник (Treugol'nik) |
| Ontological term has school analogue | Теорема о площади треугольника по сторонам (Teorema o ploshchadi treugol'nika po storonam) | Формула Герона для треугольника (Formula Gerona dlya treugol'nika) |
| School term is absent | Теорема о пересечении чевиан треугольника (Teorema o peresechenii chevian treugol'nika) | – |

Links to Wiki articles, it was decided to introduce as additional educational content. However, their main function is the integration of the OntoMathEdu ontology into the cloud of open connected data, which can also be connected with other ontologies. The content of the article may differ in Russian and English. In particular, for the term *Теорема Фалеса* (*Teorema Falesa*) literal translation will be *Thales's theorem.* The Russian-language article corresponds to the article *Intercept theorem*, where the content indicates that the *Thales's theorem* option is also possible, which suggests a different theorem – *Theorem about the angle based on the diameter of a circle.* To eliminate the problem of translation and substantial difference between articles, links to educational resources are introduced in two languages: in Russian – *Russian educational resource* and in English – *English educational resource.*

The selection of educational resources is based on the educational level. For example, the concept *Triangle* on an educational resource may contain extensive or analytical definitions. An extensive definition in school literature is used in the early stages of

studying a concept, and an analytical definition in later ones. In the analytical definition of the concept, theorems and consequences from them are added to ensure a higher level of training for students. As a rule, Wiki articles contain analytical definitions. Links to educational resources are added based on extensive definitions. The presence of such links will be an important factor in the formation of recommendation systems in accordance with the individual trajectories of students.

### 3.2 Selection of Geometric Concepts for OntoMathEdu Ontology Using Russian and English Educational Literature

In the selection of geometric concepts, Russian textbooks on geometry, approved by the Ministry of Education of the Russian Federation, were used [9–13]. The ontology was filled with terms of planimetry in English by searching for terms in English-language textbooks on geometry [14–18], using of Russian-English dictionaries ABBY Lingvo, Multitran, translation of terms in complex terminological structures and the search for terms on foreign educational sites such as Encyclopedia of Mathematics, Lexico.com, MathIsFun etc.

An analysis of foreign textbooks made it possible to determine the substantive and methodological differences of geometry courses.

The following items were highlighted:

- concepts of the designed ontology that are absent in English-language textbooks: ломаная (lomanaya), самопересекающийся многоугольник (samoperesekayushchiysya mnogougol'nik), равносоставленные фигуры (ravnosostavlennyye figury), равновеликие фигуры (ravnovelikiye figury) and etc.
- concepts that are absent in Russian textbooks: kite, dart, alternate interior angles, alternate exterior angles, complementary angles, supplementary angles.
- the ambiguity of approaches to the definition of certain terms and the designation of figures. In English geometry textbooks, the designation of the ray coincides with the designation of the vector, the concept of opposite rays is introduced, in Russian textbooks there is the concept of opposite vectors. The concept of vector itself is not presented in most analyzed English-language textbooks to study. Nevertheless, the notion of parallelism is applied to vectors, and the notion of collinearity is applied to straight lines and points, in Russian textbooks, on the contrary, lines are parallel, vectors are collinear.

As a result, terms that were not found in English-language textbooks were translated using Multitran, ABBY Lingvo online dictionaries, and literal translation. Terms translated from Russian that do not have an equivalent in English-language textbooks are indicated with a special label in the ontology. For example, the concept *Дельтоид* (*Del'toid*) has been added to the ontology in Russian, and the label *Additional program* has been introduced for this concept. For the term *Накрест лежащие углы* (*Nakrest lezhashchiye ugly*) the literal translation *Alternate angles* is added, but there is a label corresponding to the Russian school. In the ontology projection in English, there are two terms *Alternate interior angles* and *Alternate exterior angles*, which in the projection in Russian also have a literal translation.

### 3.3 The Influence of Linguistic Features on the Construction of Selected Geometric Concepts in a Joint Hierarchy

The need to build selected geometric concepts into a joint hierarchy, to distinguish generic relationships led immediately to the problem of the absence of terms in the language of school mathematics and the problem of using the singular or plural of individual terms in the names of classes, subclasses, and instances.

**The Problem of Translating Terms into English**

*Introduction of Missing Terms for Ontology Design.* For the intellectual formalization of the subject area, it was necessary to add ontological terms that are not used explicitly or implicitly in the course of school geometry. So, to combine all the geometric figures, the areas of which can be found in the course of school mathematics, two subclasses *Неограниченная часть плоскости* (*Neogranichennaya chast' ploskosti*) and *Ограниченная часть плоскости* (*Ogranichennaya chast' ploskosti*) were added in the class *Часть плоскости* (*Chast' ploskosti*). Such terms are not used in school mathematics and there are no terms close to them. There are terms that are used in the course of school mathematics, but in an implicit form. For example, the concept *Взаимное расположение окружности и многоугольника* (*Vzaimnoye raspolozheniye okruzhnosti i mnogougol'nika*) does not occur in such a formulation in teaching, but is implied when we teach inscribed and described circles of polygons or encounter other arrangements of a polygon and a circle in geometric problems. The inclusion of these terms creates a good framework for subject ontology. Due to the absence of such terms, the problem of their translation into English arose. It should be noted once again that these terms will not be present in the projections of educational otology in Russian and English. Examples of added ontological terms and their literal translation into English are presented in the Table 3.

**Table 3.** Examples of added terms

| Ontological term in Russian | Literal translation into English |
|---|---|
| Ограниченная часть плоскости (Ogranichennaya chast' ploskosti) | Bounded part of a Plane |
| Теорема о соотношении углов и сторон в равных треугольниках (Teorema o sootnoshenii uglov i storon v ravnykh treugol'nikakh) | Theorem about the ratio of angles and sides in equal triangles |
| Свойство четырехугольника (Svoystvo chetyrekhugol'nika) | Quadrilateral property |

*Disagreement with Literal Translation.* Most of the terms are complex terminological structures. For example, in the geometry course of a Russian high school there is a theorem *Первый признак подобия* (*Pervyy priznak podobiya*). Literal translation of this term is *First criteria of triangles similarity*. In English-language textbooks, this theorem is called *Angle-Angle (AA) similarity theorem*. On the one hand, both names (Russian and English) correspond to the same theorem, on the other hand, the question arises of the appropriateness of using a literal translation from Russian into English. Since the developed ontology is not only informative, but also educational in nature, it was decided to use several use cases in both languages, if any, to provide a better understanding of Plane geometry by foreign students and to adapt to the content of Russian textbooks.

**The Problem of Using the Singular or Plural**

In ontology, the inclusion of concepts only in the singular or only in the plural is fundamentally important.

At the initial stage of ontology design, it was decided to use geometric concepts in the names of classes and instances singularly. When developing an ontology projection in English, the problem of distinguishing between the use of the singular or plural of some terms was revealed. As a rule, it is customary to use the singular in dictionaries and subject indexes, however there are a number of terms that have the plural.

In Russian textbooks and mathematical dictionaries there are a number of terms expressing paired concepts in geometry and presented in the plural. For example, вертикальные (смежные, односторонние, соответственные, накрест-лежащие) углы; коллинеарные (сонаправленные, противоположно направленные) векторы; равновеликие (равносоставленные) многоугольники; параллельные (перпендикулярные) прямые; пропорциональные отрезки, касающиеся окружности и др. These concepts can be found in the singular in the framework of a specific context: прямая, параллельная прямой, угол, смежный с углом, etc. It was found that some of these paired terms are found in Russian and English textbooks and dictionaries, both in the plural and in the singular.

Due to the problem of translating such concepts into English, where the plural concepts are mainly used for paired concepts, it was decided not to use the singular. As a result of this approach, a new hierarchy *Mutual arrangement of geometric figures on a plane* was added to the ontology. For example, the concept *Vertical angles* is included in the hierarchy of materialized relations of the subclass *Angles mutual arrangement* (Fig. 1). Initially, it was planned to make this concept a subclass of the *Angle* class in the type hierarchy (Fig. 2). Similar pair concepts were also included in the *Mutual arrangement of geometric figures on a plane* hierarchy.

### 3.4 Creating Different Kinds of Relationships Between Concepts

**Ambiguity of Terms.** The translation of mathematical terms in the design of ontology requires uniqueness of meaning. However, V.N. Shevchuk notes that even within a specific terminology, a technical term can be ambiguous, from which it concludes that

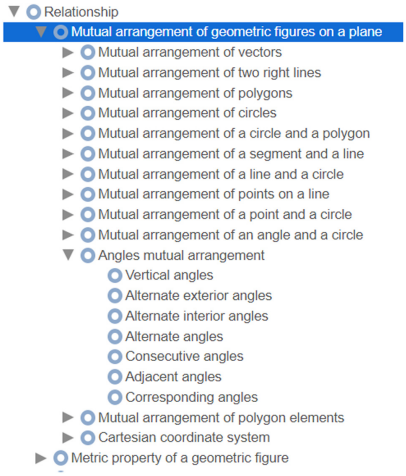


**Fig. 1.** Mutual arrangement of geometric figures on a plane hierarchy

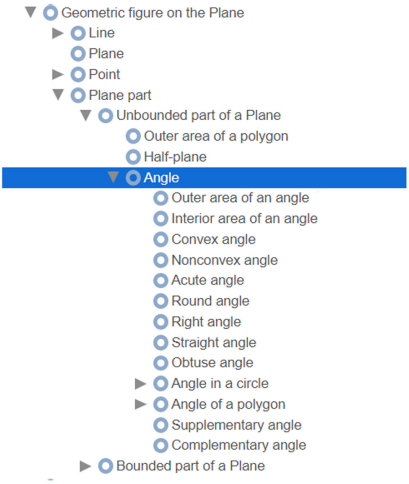


**Fig. 2.** Angle hierarchy

unambiguity is not a property of the term, but only a requirement that is presented to it [19].

Consider approaches to defining terms Circle, Circumference и Disk (Disc) in the following resources: Lexico.com (by Dictionary.com and Oxford University Press), Encyclopedia of Mathematics, Wikipedia (Table 4).

The table shows that in English there is a problem of substitution of concepts: *Круг* (*Krug*) is defined as a curve and as a limited part of the plane, *Окружность* (*Okruzhnost'*) is a plane curve and distance, *Диск* (*Disk*) is considered a limited part of the

**Table 4.** Examples of differences in definition of terms

| Term<br>Source | Circle | Circumference | Disk (Disc) |
|---|---|---|---|
| Lexico.com | A round *plane figure* whose boundary (the circumference) consists of points equidistant from a fixed point (the centre)[a] | The enclosing *boundary* of a curved geometric figure, especially a circle[b] | – |
| Encyclopedia of Mathematics | A closed *plane curve* all points of which are at the same distance from a given point (the centre of the circle) and lie in the same plane as the curve[c] | – | The *part of the plane* bounded by a circle and containing its centre[d] |
| Wikipedia | A circle is a *plane figure* bounded by one line, and such that all right lines drawn from a certain point within it to the bounding line, are equal. The bounding line is called its circumference and the point, its centre[e] | The circumference of a circle is the *distance* around it[f] | The *region in a plane* bounded by a circle[g] |

[a] https://www.lexico.com/definition/circle
[b] https://www.lexico.com/definition/circumference
[c] https://encyclopediaofmath.org/wiki/Circle
[d] https://encyclopediaofmath.org/wiki/Disc
[e] https://en.wikipedia.org/wiki/Circle
[f] https://en.wikipedia.org/wiki/Circumference#Circle
[g] https://en.wikipedia.org/wiki/Disk_(mathematics)

plane. In Russian, *Окружность* is uniquely expressed by a plane curve, *Круг* is a part of a plane.

In addition, it was revealed in geometry textbooks [14–18] that both the perimeter (circumference) and area are found for the term *Circle*. Obviously, finding the area is possible only for planar figures of dimension 2. If we take *Круг* as a *Circle*, then using the same term for different concepts entails the problem of designing ontological dependencies.

As a second example, the terms *Линия* (*Liniya*) and *Прямая* (*Pryamaya*) can be used to denote various objects. In English, the term *Line* means both *Прямая* and *Линия*, therefore, it is possible to understand the meaning of the term only in a specific context, which contradicts the property of accuracy and independence of the term from

the context within the framework of specific terminology [20]. It is also impossible to refuse the use of the term *Линия* in ontology, since it is a generic concept of the *Geometric figure on a Plane* class.

Since in the future the ontology will be used in recommendation systems of electronic courses, it is important that the "address" of the object in the ontology is unique. The presence of terms with the same name and different meanings will not allow using the name of the object as this "address". Therefore, to solve the problem of the ambiguity of terms, special labels are introduced into the ontology that will perform the function of structuring and unambiguous definition of an object.

**Synonyms of Terms.** The presence of several versions of translations of the same term also complicates the process of filling the ontology with terms and establishing links between concepts. For example: Катет – leg of right triangle, catheter, leg, side; Кривая второго порядка – point conic, quadratic curve, second-order curve, curve of the second order [2]. For such terms in the ontology, several translation options are presented.

## 4 Conclusions

The problem of translation of professional terms is urgent. In the article [21] describes the problem of translation of educational terms. The importance of mastering special terminology in several languages is noted in view of the transition from the national education system to the global one in the process of internationalization. At the same time, the expansion of international communication in the educational space requires a transition to a polylingual basis. The initiative to create a network of polylingual educational complexes in the Republic of Tatarstan by 2022 was supported by President of the Russian Federation V.V. Putin[1]

In this article, we described the problems of translating the terms of the OntoMathEdu ontology, which contains more than 600 concepts of the school course of Plane geometry. Thanks to translation problems, a new concept of ontology construction has emerged by combining three language projections, which may have a different set of terms for the respective languages. The ontology is filling by new terms in Russian and English thanks to the continuous analysis of textbooks and dictionaries.

In the future, the developed ontology will be expanded to other sections of the school mathematics course in three languages. OntoMathEdu is preparing to be introduced into the electronic course of Plane geometry for schoolchildren engaged in advanced mathematics and preparing for final exams. The ontology will be used as a database for searching information in an electronic course and marking up educational material.

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[1] https://sntat.ru/news/science/03-04-2019/polilingvalnye-shkoly-shaymieva-obuchenie-na-treh-yazykah-internat-dlya-vunderkindov-i-filosofiya-soglasiya-5646642.

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