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Official URL: DOI:10.4018/IJITSA.2019070104

To cite this version: Ortiz Esparza, Miguel Angel and Muñoz Arteaga, Jaime and Mendoza, José Eder Guzmán and Canul-Reich, Juana and Broisin, Julien *An Eco-System Architectural Model for Delivering Educational Services to Children with Learning Problems in Basic Mathematics.* (2019) International Journal of Information Technologies and Systems Approach, 12 (2). 61-81. ISSN 1935-570X

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An Eco-System Architectural Model for Delivering Educational Services to Children With Learning Problems in Basic Mathematics

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ABSTRACT

A large diverse amount of educational content can dynamically contribute to the construction of basic knowledge for elementary school children. These contents can be used to develop or expand such knowledge and this becomes different when it needs to be applied to children with learning problems in basic mathematics. Then, it is necessary to manage effectively educational resources. The current work proposes the use of an architectural model in order to support teaching activities of a multidisciplinary group of specialist in inclusive education. A case study presents here some examples of teaching activities such as the specification of context and the management of educational resources according the learning problems of children at elementary school.

KEYWORDS

Basic Mathematics, Digital Eco-System, Educational Resources, Learning Paths, Learning Problems, Mobile Applications, Software Architecture

1. INTRODUCTION

Education is considered the engine that drives the economies of a world so competing today. Thus, a country with high education rates among its population has higher expectations in economic, political and social development. However, some of the problems we have in the delivery of knowledge in our country, are based on the exact sciences specifically in mathematics, this affects both people who don´t have a learning disability and those who have.

DOI: 10.4018/IJITSA.2019070104

A learning problem consists of problems not associated with severe motor or cognitive disability such as acalculia, dyscalculia, dyspraxia, dyslexia or any language disorder, but it takes care of all those factors such as the difficulties of calculation, difficulties in the solution of mathematics problems or related to personal aspects, some of these problems are deficits of sustained attention, deficit in the use of the work memory, deficit in the coherent representation in the work memory of the problem components, etc. (Romero-Pérez & Lavigne-Cerván, 2005).

According to UNESCO (s.f.), information and communication technologies (ICT) can contribute to universal access to education, equality in education, quality teaching and learning and professional teachers´ development, as well as the efficient management and administration of the education system, it is for this reason that it applies a broad and inclusive strategy regarding the promotion of ICT´s used in education. Access, integration and quality are among the main problems that ICT´s can approach. Today exist a lot of educational resources in the network, which is being used as a new way of obtaining knowledge, so it is necessary to sort, classify and manage these resources (Chuang & Shen, 2008) with the support of a group of experts in educational and pedagogical topics called "the multidisciplinary group" in favor of children with mild learning problems in basic mathematics, this multidisciplinary group will help to distribute educational resources through services, using learning paths, workflows and user tasks to model the knowledge of each of the communities, all this within a software architecture. This architecture offers open educational resources through services to the communities of children with learning problems according to the community´s needs both general and specific, these resources are cataloged according to the specialists about learning acquisition, they can give the guidelines for different learning levels.

Nowadays, e-learning has been more widely accepted as a new form of learning and it is growing at an accelerated rate (Zhen *et al.,* 2013) This generates an abundance of educational products that help to generate knowledge among students, who use those tools, but there isn´t order of use, so that knowledge can be generated but not necessarily in the most optimal forms or at least not close to the most optimal, so it is necessary to organize and produce applications according to the needs of children with learning problems that can be managed through a software architecture, this architecture contains among its characteristics the administration of services using knowledge adaptability modeling, which according to (Chuang & Shen, 2008) are one of the best ways to manage the large number of technological tools that exist today, giving it an organization and management to resources using the experts´ knowledge in pedagogy for children with learning problems.

Current work considers the use of an architectural model (Pressman, 2002) in order to identify learning paths integrating services, each service as such, can be integrated into a "composition of services", i.e. the packaging of all those educational resources necessary to mitigate a specific mathematics problem, services will take educational resources from repositories that will store all those educational resources and deliver them to the communities´ individuals according to the needs specified by the multidisciplinary group, which will generate feedback about the applications´ use by the communities to improve learning paths and develop more specific applications according to the communities' needs.

Otherwise, the structure of this work begins with the introduction section in order to identify some definition such as basic education, software architectures and new methods of teaching for educational skills. The second section presents the problem-based in the lack of architectural models that help to mitigate the problems of learning in basic math for children. The third section shows the proposed contribution through the description of an architectural model. The fourth section shows a case study with two children of basic education who belong to a learning community called (USAER). In the fifth section, the related works show a comparative table of works identified in the literature and from that comparison it shows the advantages that our work proposes for the problem resolution. Finally, the conclusions are presented, and some future works are proposed.

2. RESEARCH METHOD – CONCEPTUAL DESIGN

Table 1 was made taking into account the table of the paper "Research Activities of Conceptual Design Research" (Mora *et al*, 2011) where describes the most important activities to do. Then the table below shows the most relevant activities carried out for the development of the proposed architectural model through activities. Each one of the activities present inputs, processes and outputs, obtaining as final result advances in the investigation until this is completed.

Next, the methodology used to carry out the investigation is briefly described.

As mentioned above, there is a need for the use of technology in favor of education, to help those people who require educational resources for the acquisition of educational competences, looking at it from a more specific point of view, there are communities of children with learning problems that require the adaptation and organization of a large amount of educational resources that exist in

Table 1. Research activities

Research Activities	Inputs	Process	Outputs
Activity 1 Identification of opportunities areas	1. - Initial goals. 2. - Conceptual schemas of the study subject.	1. - Selection of support material. 2. - Review of the state of the art. 3.- Research limitation 4.- Contribution identification 5.- Test an architectural model for communities of children with learning problems 6.- Check that the use of this architecture helps to mitigate learning problems in learning communities	1. - Re addressing research. 2. - Rethinking the contribution.
Activity 2 Selection of method to be used	1.- Conceptual study units 2.- Confirmation or redirection of research goals	1. - Purpose definition of the research. 2. - Search for related works. 3. - Delimitation in the model's selection.	1. - Work plan. 2. - Initial contribution schemes based on the state of the art. 3. - Scheme of the initial model.
Activity 3 Conceptual design	1. - the Initial idea of the architectural model. 2. - Conceptual schemas of the study unit.	1. - Design of the initial architecture 2. - Search for related works. 3. - Delimitation and model iteration	1. - Conceptual design of the debugged architectural model
Activity 4 Assessment of evaluation models and instruments	1. - Conceptual design of evaluation tools	1. - Identification of learning communities 2. - Application of the architectural model 3. – Instruments validation by the multidisciplinary team. 4. - Usability and user experience testing.	1. - Model and evaluation instruments proved and validated in learning communities. 2.- Usability and User Experience Questionnaires
Activity 5 Analysis and synthesis of data	1. - Model and evaluation instruments proved and validated in learning communities. 2. - Usability and User Experience Questionnaires	1. - Analysis of the data generated from the Usability and User Experience questionnaires. 2.- Analysis of the architectural model use to compare it with the initial goals	1.- Expected contributions and collateral knowledge of the design, implementation and architectural model evaluation

the network and at the same time requires the knowledge of experts on issues of inclusive education to carry out this research.

Through this need, the creation, distribution, use and feedback of educational resources is required, for which the use of a service-oriented architecture is proposed, with which the delivery and creation of the necessary educational resources is managed and orchestrated. to cover the problem.

Because above, our area of opportunity is based on the need to use technology in favor of learning communities for children with learning problems that require the use of educational resources provided through the recommendations of a multidisciplinary group of experts.

For this research our goals are based on knowing the impact of the use of an architectural model through the use of its different sections, through a method of observation and surveys of teachers of inclusive education.

Due to the above, it was necessary to carry out research on the state of the art and to delimit the impact of research through the related works shown in section 4, and the architectural model was tested in learning communities for children with learning problems.

Based on the experience of use in a community, the impact of the architectural model was redefined, and the state of the art was revised again to narrow and modify the architectural model oriented to services.

As part of the methodology, two learning communities were searched, and the final architectural model was applied, usability and user experience surveys were conducted to know the impact of the technologies on both children and special education teachers.

We took as a reference the testimonies of the children and support teachers, it was a qualitative evaluation from the point of view of the support teacher.

Finally, we analyzed the data and comments made by the multidisciplinary group to improve our architecture in future work.

3. PROBLEM OUTLINE

Nowadays, there are a lot of children who present learning difficulties in areas such as math; these problems make learning difficult from the early people stages (SEP, s.f.). Current work focuses on learning problems that correspond to basic mathematics for children who are between the ages of six and twelve, these ages make up the early ages of knowledge in the mathematics area, and these problems can be more easily detected when the child presents some difficulty in acquiring basic mathematical knowledge. These types of problems delay or limit development in their education and basic training, children are denoted by not achieving the expected average results like a student of their age (Publica & Sonora, 2010; Marchesi-Álvaro, 1990), these problems can be classified for a better understanding according to Piaget´s pedagogical approach in two great branches as are the logical and infralogical operations (Piaget, 1973) in order to be able to attend to them in a more specific way.

As it was previously mentioned in the first section, one of the problems is the inadequate use of technologies as a tool to acquire certain basic mathematics skills and thus mitigate the problems that can present children. Combined with this problem is the misuse of the large number of mobile applications and educational resources for the acquisition of mathematical competence, in particular the way in which these technological tools are administered, which contributes to reducing the problems of children with difficulties of learning, according to (Chuang & Shen, 2008) the results can be obtained using simply applications, due to the own technological and the human-computer interaction offered by the mobile devices, but it seeks to obtain the necessary resources according to the communities of learning and children´s profiles through the correct use of mobile applications.

Our main problem is the lack of software architectures based on digital ecosystems oriented to services that help to organize and coordinate the delivery of educational resources for communities of children with learning problems.

Currently there are architectures that model the transition of knowledge and help to manage educational resources for people with learning problems in different areas and academic degrees, but these architectures don´t implement the experts´ knowledge in the areas of education (multidisciplinary groups) and neither they use user profiles to deliver specific educational resources to the members of each of the learning communities. On the other hand, they are not oriented towards basic mathematics as in this work is proposed.

So, it´s necessary to make the proposal shown in later sections. As part of the context of the problem, the following factors were identified for teaching basic mathematics for children with learning problems at basic education level (Fuentes-Cardona et al, 2011; INEE, 2004):

1. The main problem in basic education is found in the failure rates in reading, writing and mathematical skills;
2. There are problems of availability and access to the contents necessary to work in the inclusive education at the basic level;
3. Lack of support for constant teacher training;
4. The absence of diffusion means to apply the educational models;
5. Integrate new pedagogical approaches appropriate for the inclusive teaching of basic mathematics;
6. Changing the technologists´ attitude to collaborate and meet the teachers´ requirements about ICT used by them.

But our main problem focuses on the need for a service-oriented architecture that helps the creation, distribution, consumption and feedback of specific educational resources for children with learning problems in basic mathematics through user profiles.

4. THEORETICAL BACKGROUND ON ECO-SYSTEMS FOR EDUCATIONAL SERVICES AND RELATED WORK

Ecosystems are a complex network of actions that go together between two great entities such as producers and consumers, which in turn can be considered both providers and consumers and vice versa generating the prosumers, who are those who consume a product (resource) within the ecosystem already in turn produce a product for some consumer within an environment called ecosystem.

Within an ecosystem can be characterized several important components that compose it, among the most important is what characterizes it as an open and dynamic environment where the interaction and collaboration between the entities are highly active (Guzmán-Mendoza, 2016), this dynamic keeps the ecosystem alive in addition to that generates a constant improvement so that the producers and consumers of the ecosystem evolve for an optimized coexistence in favor of the same ecosystem.

In general, an ecosystem is considered as a recent terminology and is generated from the experiences of the analysis of the natural existence of living beings in the natural ecosystem where the human being lives. From this, different models of business ecosystems have been created, from which a digital ecosystem derives from the rise of the internet and telecommunications in the present human life system, together with the evolution of the new ways of doing business and the implementation of new technological innovations.

One of the most important objectives of ecosystems is the continuous improvement of communication between agents and the internal structure of business ecosystems, for which there is constant feedback and improvement of communication, consumption and production processes as a part of these ecosystems.

Digital ecosystems as mentioned above are based on a complex ecological environment, where digital organisms form a dynamic and complex interaction between them consuming and producing resources such as services for the survival and improvement of the same, that is why a digital ecosystem must contain species and service technologies to ensure the survival of ecosystems. In

this sense human beings, business organizations and information technologies can be considered a kind of species. Organizations look for business environments because of the need to interact with customers, need interactivity to improve their inputs, processes and outputs, as well as ensuring sustainability to continue producing and consuming. Another species is the information technologies that constantly improve in the rhythm that generates the supply and the demand for new products to be able to sustain itself within the ecosystem. Similarly, in education, certain specific characteristics can be considered in an educational ecosystem, where there are producers, consumers and prosumers. Some papers (Guzmán-Mendoza, 2016) talk about the importance of using ecosystems as a support for education, within which they identify the fundamental parts of an educational ecosystem.

Educational ecosystems are based on the reduction of the digital divide in any field of knowledge, as long as it is well directed towards the specific objectives that are desired, generating knowledge through educational services or literacy directed towards the consumer species and as a consequence of this, to mitigate the lack of knowledge in those species grouped in learning communities.

The service-oriented approach is used frequently to develop educational ecosystems, that is, the specification of resources through well-defined services according to the specific characteristics of each individual or learning community. In fact, an educational ecosystem is composed of several entities such as educative content, services, repositories, user profiles and graphical user interphase. Each one of them has a fundamental function in the good functioning of the ecosystem and the survival of the same, for example, the content producers generate specific educational resources necessary for a learning community or an individual taking into account specific characteristics. A set of digital competences puts together skills concerning to mitigate a specific problem, users are usually the students or apprentices who require products to improve their literacy or education skills and finally, the distribution services considered the medium by which identifies and distributes those specific resources for each of the learning communities.

In the literature on e-learning and computer science there is a great variety of works related to this topic, in this section we analyze a series of works, in their characteristics and they will be compared to the present work.

The first work mentioned in the previous table presents interesting characteristics in the management of a model of teaching competences based on the characteristics of the learning

Table 2. Characteristics in the management of a model of teaching competences

	T1 (Chuang & Shen, 2008)	**T2 (Zheng et al, 2013)**	**T3 Guzmán-Mendoza et al, 2016)**	**Current Proposal**
Model of Deliver	✓			✓
Implementation strategy	✓	✓	✓	✓
Pedagogical Approach				✓
Multidisciplinary Team	✓		✓	✓
User-centered				✓
User Profiles				✓
Feedback	✓	✓		✓
Mobile devices		✓		✓
Basic Mathematics		✓		✓
Architectural Model				✓
Number of Communities	5	1	3	1

communities, which are reflected in the strategies for the implementation of resources and information technologies, some of these are good practices in the use of these tools, i.e. the best strategies are used in the use of information technologies in favor of learning communities and their corresponding individuals that integrate them, in addition to good practices this work proposes the use of the knowledge of a multidisciplinary group composed of experts in educational subjects who also have previous experiences in education to use them according to the needs and characteristics of the community that they want to attend through the educational resources, these people besides providing cone also analyze the functions of analysis of the use of literacy resources through the feedback of the use of their educational resources by the people who make up the learning communities.

On the other hand, this work presents an approach that lacks a pedagogical orientation, that is to say, it does not have the guidance of an expert in pedagogical knowledge that guides and indicates the best practices for a learning community or specific individuals to obtain the knowledge required according to the knowledge profiles that they present and consequently the designs of educational resources do not show to be centered on the user, that is to say, they do not show specialized designs for the needs that each one of the members of the learning community, which leads us to conclude that specific user profiles were not used for the creation of educational resources, another point is that it is not based on a specific competence, ie it is not based on mathematics or natural sciences, which makes it very general and generates problems of content specification according to the needs of c one of the communities, another of the differences is that it does not mention the use of mobile devices or any current tool with a highly playful nature for the purpose of better utilization for learning communities, and as a core part of this comparison, mentions the use of a software architecture that helps to guide, model and control the production, administration and consumption of the educational resources of the community in question, which leaves to the imagination the process of how the processes of production, delivery and consumption of educational resources by the proposed model.

The second related work shows some important characteristic points in the use of educational resources, one of them is the use of a strategy of implementation of educational resources, that is to say a strategy of using these resources through the administration of the same and the specific order that should have the consumption of these educational resources to achieve optimal results in the acquisition of knowledge, the educational resources mentioned in this paper mentions a relationship with basic math competence but is not focused directly and specifically towards math competence, educational resources generate feedback through observation and analysis, which is used to improve the following productions and iterations of products for the community in question.

On the other hand, like the previous work, this work does not show an architectural model for the production, allocation and consumption of educational resources, in turn this work lacks a pedagogical approach necessary to orient the production, distribution and consumption of the products that they have to generate a good employment of them, another important point that was detected in this is that it does not have signs or indications that the developments are focused on the user work is not shown in this work signals that the developments are centered on the user so that educational resources are considered as standard without specifications according to the needs of members of learning communities, on the other hand does not show the support of a group of experts in education, commonly called group multidisciplinary, who generate the requirements and specifications of development for a better design and consequently a better or use of the resources to be used by the members of the community and as part of the above observations it can be deduced that in this work user profiles are not handled, that is to say, they do not take into account the characteristics or specific requirements of each one of the members of the communities to create the educational resources and finally in this work does not mention the use of an architecture that helps to model, create and control the production and consumption of educational resources.

The third work mentioned in the table shows two interesting points in the literacy strategy as they are a strategy of implementation and use of educational resources and on the other hand the strategic

support of a multidisciplinary group of experts that supports in the work of detection, classification and use of the educational resources generated for the individuals of the ecosystems.

Within the state of the art also found an article that speaks of mathematical competence for children of basic education (Guerrero Garcia, González Calleros, Vera Cervantes, Navarro Rangel, & Muñoz Arteaga, 2017), it was found that shows strategies of imparting knowledge such as the demonstration of videos of the subject, the presentation of images of the subject, discussion of the subject, etc. Same that can be considered as part of a knowledge modeling oriented to the development of mathematical ability, but it is limited to a very small and complex area such as the fractions in basic education in Mexico.

On the other hand, there is no mention of the use of a group of experts in basic education that accompanies the construction of educational resources according to the user's profiles, it is simply shown as a selection menu of educational resources.

Another part to consider is that it does not mention a feedback that allows to improve the construction of educational resources, be it videos, debates or images related to the theme of fractions.

As the last point does not mention the use of an architecture or a structure that mentions the flow of educational resources, they are only mentioned as a portal with very well-defined sections for the topics of fractions in their different phases.

On the other hand, there is no indication of the use of a model or strategy to implement the use of educational resources, it also requires a pedagogical approach that helps to guide the development of educational resources for its correct use, this work has no indications of achieving or developing educational resources focused on the user for their correct employment and therefore does not consider the use of user profiles, also within the strategies does not consider feedback as a strategy to improve the products developed, another aspect to consider is the lack of employment of mobile devices as a playful form of learning, is not based on some basic competence such as basic mathematics, ie is used in general for multiple skills which can generate a lack of specification of teaching processes and lastly no mention is made of the use of an architecture for the control, and development of educational resources, leaving aside the interactive part that an object-oriented architecture can provide for the improvement of the production and consumption of specific educational resources.

Unlike the previous works, the proposed work has an architectural model based on the operation of a digital ecosystem that helps to model the educational resources, data and services that help to communicate the different phases of the inclusive educational ecosystem. a feedback from the learning communities through the use of these, these experiences are analyzed by a multidisciplinary group of experts to make improvements and recommendations necessary for each of the necessary skills of the specific profiles that each of the members of learning communities, which have been previously diagnosed by a group of experts on issues of inclusive education, this takes into account the specific needs of the user and are grouped by community, so it can be said that architecture has trended towards user-oriented development. the above-mentioned characteristics the present work contains a pedagogical approach of Piaget to orient the teaching processes for the members of the learning communities based on basic mathematics, lastly encompassing of the characteristics described above it has an architecture based on an ecosystem which supports the management (consumption and production) of educational resources for children with learning problems in a specific way, generating the feedback needed to iterate and improve those products.

5. ARCHITECTURAL MODEL DESIGN

In order to mitigate some issues specified in the previous section, current work proposes the use of architectural model (Muñoz-Arteaga et al., 2017).

Through this architectural model, we aim to achieve different research objectives, among which the following stand out:

- To know the impact that the use of specific educational resources has on children with learning problems in basic mathematics;
- Know the importance of the feedback of the use of educational resources by children as well as by the multidisciplinary group;
- Investigate the importance of the use of specific educational resources directed through knowledge acquisition modeling;
- Finally, demonstrate that the use of service-oriented architecture helps to mitigate the specific problems of learning communities in the basic mathematics competency.

This model advocates the use of educational resources under mobile technology as a support in the learning of basic mathematics, here it is proposed to organize educational resources, and then to make these resources available to the end user through online learning services. Availability and access to educational resources are designed according to learning paths (Gloogle, 2015) so that they offer educational resources according to the specific mathematical ability required in each learning community. It is important to say that a set of repositories are used to store the educational resources those are developed a priori; other repositories are for storing evaluations and communities and children´s user profiles. The components mentioned above are integrated by layers within an architectural model. Thus, this model is composed of a set of production layers of educational resources such as the content providers layer, repositories, service composition and use of learning objects and within the educational resources consumption layer are the sections of knowledge adaptability modeling, levels of mathematical skills, collaborative work, and learning communities. The set of previous layers are presented in the following architectural model of Figure 1.

The model of Figure 1 updates some layers of previous work (Muñoz-Arteaga *et al*, 2017) and it was tested in other learning community, the layers interact with each other to achieve the objective of helping to mitigate the problems of children with learning difficulties, the architecture starts the flow with the providers of educational resources that generate educational resources according to the requirements and the communities´ profiles, then the educational resources are classified and stored in repositories joined with the user profiles and the evaluations, these evaluations will be obtained from the use of those resources, once classified and stored, the multidisciplinary group will make compositions of services, that is to say, two or more resources will be joined to mitigate certain specific problems, to continue the use of resources. Before these resources are used, there must be a knowledge adaptability modeling that is the planning of the use of educational resources through models, these models must correspond to a level of knowledge acquisition to guide the child's progress, this should be planned, monitored, applied and evaluated to the learning communities by a multidisciplinary group, the following sections are shown in greater detail in the following sections.

5.1. Learning Communities

A learning community can be considered as a population of individuals that are grouped according to the similarity of their characteristics (Figure 2), those communities can belong to public or private education.

Each community is considered as a learning community because its purpose is to meet the knowledge needs of its members, such as children; so, it requires a set of educational resources. The proposed architectural model advocates the production of educational resources and their use. For this it is necessary to take into account both producers and consumers to attend the education of children with learning problems, thus identifying a set of educational resources to attend to the creation of more homogeneous learning communities. Thus, forming learning communities as homogeneous as possible it can obtain more enriched requirements that allow specifying; the mathematical skills to be acquired, as well as the necessary infrastructure, characteristics and types of learning contents, and later, to create the most appropriate educational resources according to the requirements. In this way, it is possible to create models of use of differentiated learning objects

Figure 1. The Architectural model to assist children with learning problems in basic math

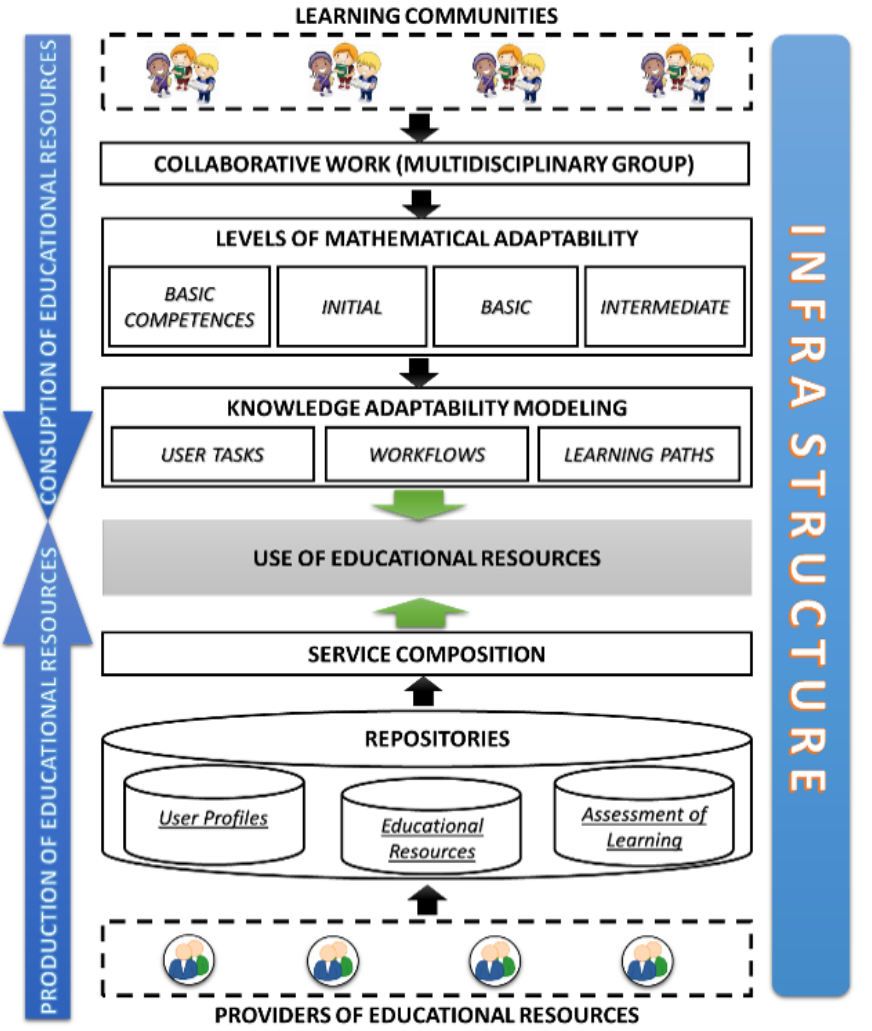


Figure 2. Representation of learning communities

capable of adjusting to the real needs of each children´s community with learning problems, this represents to be able to specify models of integral solutions of ad-hoc mathematical educational resources for the learning communities.

5.2. Collaborative Work

The collaborative work is carried out with the participation of a multidisciplinary group that includes psychologists who performs psychological analysis to know the possible causes of the children´s

educational problems, the social workers analyze the socioeconomic and familiar children´s environment to know if the problems are these factors, teachers are the ones who help with regular content to integrate the students according to their age and grade, the support teachers are who deliver educational resources according to their problems and integrate strategies to improve the child´s knowledge acquisition, pedagogues are specialists in inclusive education and who support with recommendations in the child´s rehabilitation and finally the parents who play a primary role in helping with homework and collaborate with behavioral information during the treatment. All these people collaborate each one from their respective fields of work to the benefit of the creation of mobile applications and educational contents. During the design and evaluation of educational resources, this group of people has helped in order to iterate and develop educational resources that are increasingly specific according to the communities´ profiles and the elements that make them up.

5.3. Levels of Mathematical Skills

The levels of mathematical abilities refer to the understanding degrees of knowledge about the nature and real-life daily situations. In this sense, if a child has certain mathematics learning needs, it is necessary as a first step acquire a set of digital competences at the levels of "Basic Skills", "Initial", "Intermediate" and "Regular" through formal, non-formal and informal educational processes. Figure 3 showcases levels of acquisition.

In this way, when the individual makes continuous use of his daily ICT activities, he can enter more easily into a teaching process of mathematical skills, achieving thus to gradually mitigate the problems detected until the student is considered regular by the evaluations of the multidisciplinary group.

5.4. Knowledge Adaptability Modeling

The modeling layer of learning behavior is composed of conceptual models to represent the different strategies that can be offered to ease learning for children. The models (Figure 4) here are described in the specification of the user task, workflows and learning paths.

User task analysis is a technique used to describe and evaluate the required activities by a user with the purpose of achieving a goal in an interactive environment. In fact, user task is represented by a task model of educational resources. A user task model allows the user to provide an argument

Figure 3. Levels of acquisition of elementary mathematical knowledge

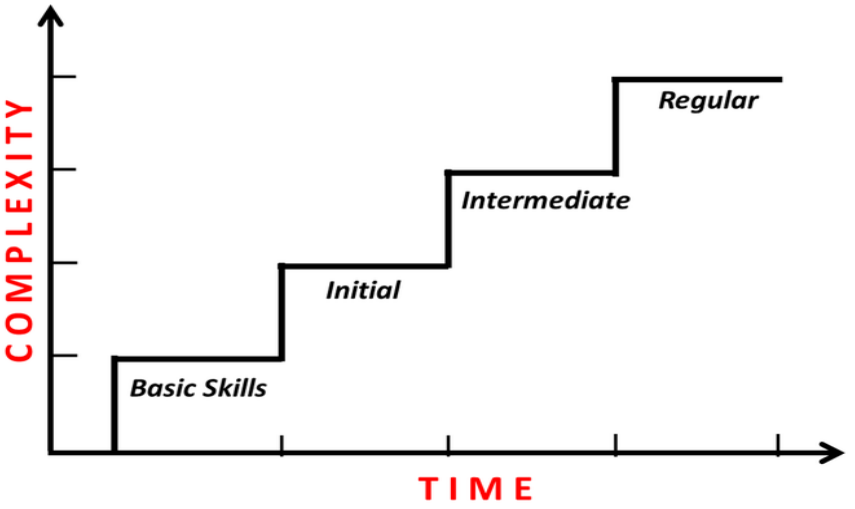
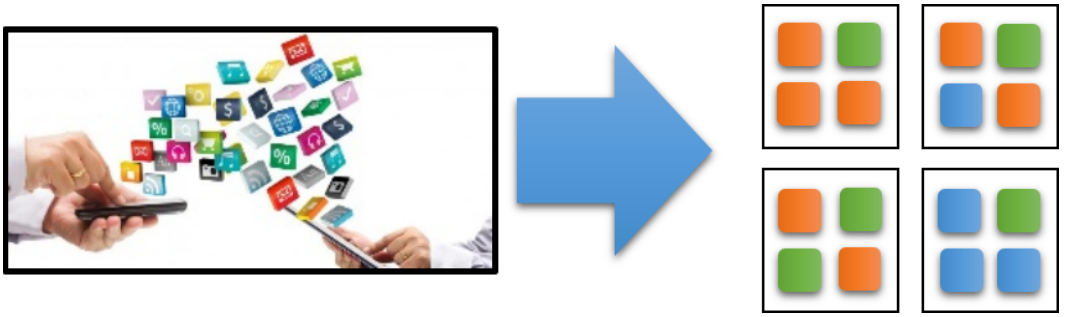


Figure 4. Models of knowledge adaptability used in the proposed architecture



necessary to reach a goal. Some of the interactive tasks that users can perform are: start an application, interact through interfaces, evaluate a request and apply for results.

After modeling the user tasks, the construction of learning paths is defined according Zhen & Zhang (2013) who defined as a product of a course, which includes the steps for a student to obtain through these routes the knowledge necessary in specific course, in each step the student assimilates certain contents corresponding to the route, which must be adapted according to a specific pedagogy. Learning paths in education have emerged as an important advantage in planning, organizing and controlling learning processes. A learning path defines the steps that should guide a student in effectively building their knowledge and skills.

Finally, the architecture integrates workflows that constitute the knowledge flows according to the behavior of the child with learning problems, that is to say, they specify the possible cases from a specific course according to progress in the acquisition of basic mathematics skills.

5.5. Use of Educational Resources

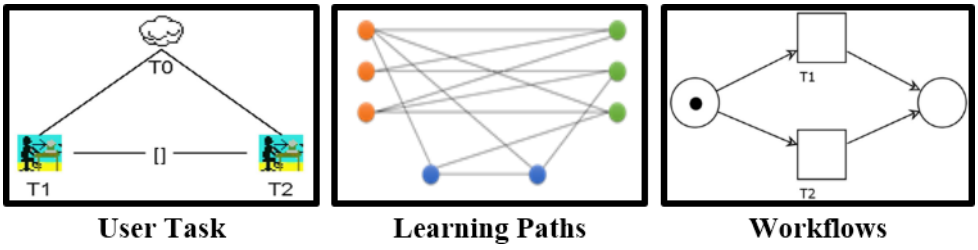
A service is defined as an activity offered by a supplier to a consumer, using the time to bring value to customers or their objects.

In this sense, based on this definition, a digital literacy service can be defined as a learning activity offered to users within a learning community that through the time increases, the users' digital competencies increase too, in other words, the use of educational resources is provided by services specifically offered to communities for the use and evaluation needed.

5.6. Composition of Services

Service composition (Figure 5) refers to the situation where an individual's service request isn´t satisfied by a single pre-existing service but can be satisfied by the appropriate combination of some pre-existing services available.

Figure 5. Composition of services through the union of several educational resources



Generally, a single service provides limited functions, so they require mechanisms of the composition of services to create services that meet the requirements and demands of users. A potential benefit of the service composition approach is that it allows new services to be created quickly, such as a combination of existing basic services, rather than being developed right from the start.

5.7. Repositories

The repositories (Figure 6) are used by institutions as a place for organizing, accessing, preserving and disseminating educational resources on a specific topic, in this case, basic mathematical applications for children with learning problems.

A producer of educational resources can also evaluate other resources created by other producers, with the aim of improving them if necessary, whit the final purpose that they can adapt them to other learning communities. As shown in Figure 6, repositories are classified into three types of services:

- **User Profiles:** These repositories are necessary to have the control of the requirements according to the members' needs of the learning communities, therefore is an essential part of the educational resources´ administration according to the presented problem and another hand, some part of these repositories provide identification services about community profiles;
- **Educational Resources:** These repositories are all those classified resources (documents, learning objects, videos, presentations, etc.) that help to mitigate a specific need for a user profile and help to strengthen the knowledge where there are learning difficulties;
- **Assessment of learning:** This is a repository that stores the evaluations, these evaluations were made based on a pedagogical profile and that help to make decisions about the user´s usability and experience to generate the necessary feedback.

5.8. Infrastructure

Infrastructure is a core part of the architecture, because it requires the same to perform an interaction of the parties, i.e. learning communities, providers of educational resources and the multidisciplinary group. This infrastructure generally includes the connection to the network (Internet), computer equipment and mobile devices as shown in the following Figure 7.

5.9. Content Providers

As mentioned in previous sections, it requires the collaboration and interaction of a number of actors (Figure 8) and the sum of their resources (technological, infrastructure, human, economic, etc.) to help to mitigate the communities' problems composed by children with learning disabilities in basic math.

Currently there are four types of actors that have been identified: a) governments, whether at the municipal, state or federal level; B) Universities, whether public or private; (C) small and medium-sized enterprises (private sector); and d) Social organizations, directly responsible for managing and implementing mathematical services projects for children with learning problems.

Figure 6. Repositories to access and reuse educational resources, assessment of learning and user profiles

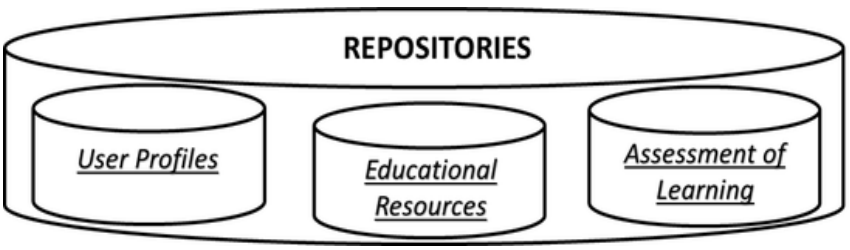
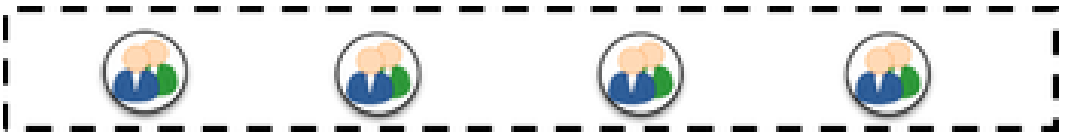


Figure 7. Necessary infrastructure for using educational resources by different learning communities

Figure 8. Providers of educational resources for different learning communities



6. CASE STUDY

The application of the proposed architectural model is presented at this section through a case study; this case study was carried out in an elementary school of México, where two children with learning problems in basic mathematics are taken into account in the Unit of Services to support the Regular Education (USAER).

As can see in the Figure 9 we present an instance of the architecture of Figure 1, in this case, the student 1 is 7 years old and he courses the second grade of elementary school and has a psychopedagogical diagnosis called Asperger. For the second student, the instance is not shown in this paper, he is 10 years old, he courses the fifth grade of elementary school and he has a psychopedagogical diagnosis called Attention-Deficit Hyperactivity Disorder (ADHD). The last figure shows the description of the instance phases of the architecture of Figure 1 corresponding to student1 "Asperger", in the upper part of the Figure 9 shows the mathematical levels of acquisition according to the specialists criteria, for the student 1 is "Initial", then it shows the mathematical skills necessary for the children, continuing with the learning paths modeled by specialists in inclusive education and also it shows the applications needed to mitigate one of the problems that the children have and finally the sequence of use of these applications based on the Learning path.

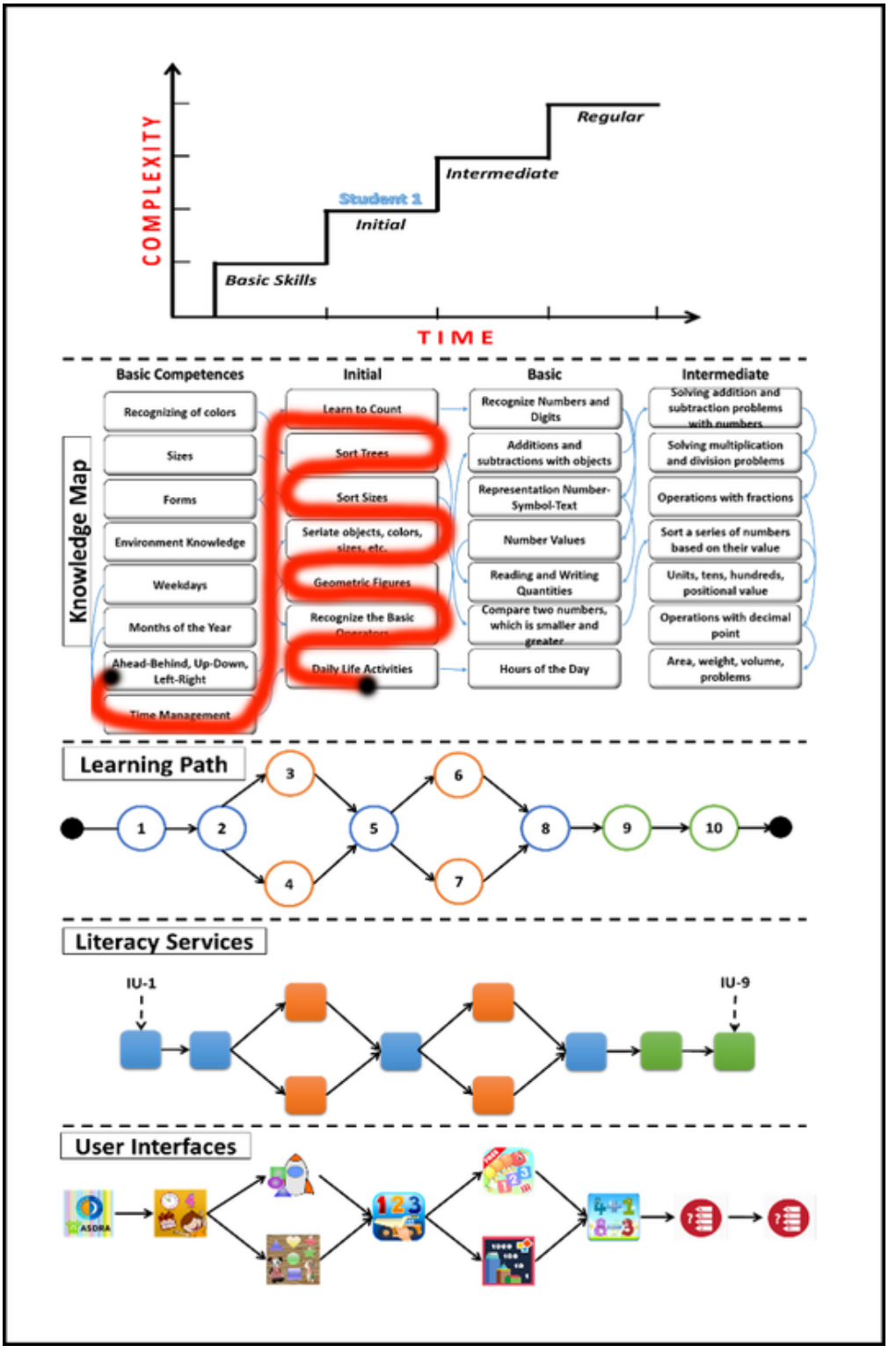
6.1. Learning Communities

The learning community involved in this case study was only one, USAER (Unit of Services to support the Regular Education) that provides assistance to those children with ADHD, Asperger, intellectual disability, etc. to give support for these children that require services distributed in different physical locations, for which it is necessary to provide support for both support teachers, regular education and parents to access to these contents through technology services.

6.2. Collaborative Work (Multidisciplinary Group)

The collaborative work for the development of mobile applications and educational resources, includes technologists, who are students and researchers of the Autonomous University of Aguascalientes, as well as all those who develop mobile applications in different parts of the planet and upload them to the Google store (Xu et al., 2012). By the USAER, which is a subsystem of the Aguascalientes Institute of Education, this institute integrates social workers, psychologists, teachers of inclusive

Figure 9. Instance of the architectural model for student 1



education, as well as teachers of regular education and parents of the USAER learning community. Figure 10 showcases the main actors of multidisciplinary team.

These collaborators during the application sessions and learning objects observed the interaction of the children with the mobile applications and how they used, in the case of the student 1, they recommended that the applications and the educational resources had content with less complexity of use, more practical, larger images and preferably the mobile device should be of the largest possible dimensions.

For these children, several recommendations were made by the multidisciplinary team, as the application should have sounds and colors that attract more attention, because the child has difficulties to retain attention in school activities.

6.3. Levels of Mathematical Skills

As a first step was detected the problems that each child had in mathematical skills so that student 1 was detected with problems in the knowledge of initial skills, i.e. problems with the representation of numbers, and skills of time-space discrimination.

The student 2 was detected with learning problems at the intermediate level, i.e. problems with arithmetic operations and solving mathematical problems raised from a real perspective.

6.4. Modeling of Learning Behavior

The modeling of mathematical knowledge is specified here through the maps of knowledge, in this case by Piaget's logical and infralogical operations (Piaget, 1973), the mathematical skills required by four necessary levels, as Figure 11 shows.

Within the modeling section of learning behavior, different tasks can be performed to indicate how to consume resources in a specific way and thus to try to optimize resources in favor of children with problems and teachers who help these children.

The learning paths (Google, 2015) for student 1 and student 2 according to the recommendations given by the specialists such are the follows.

Figure 10. Main actors of multidisciplinary team

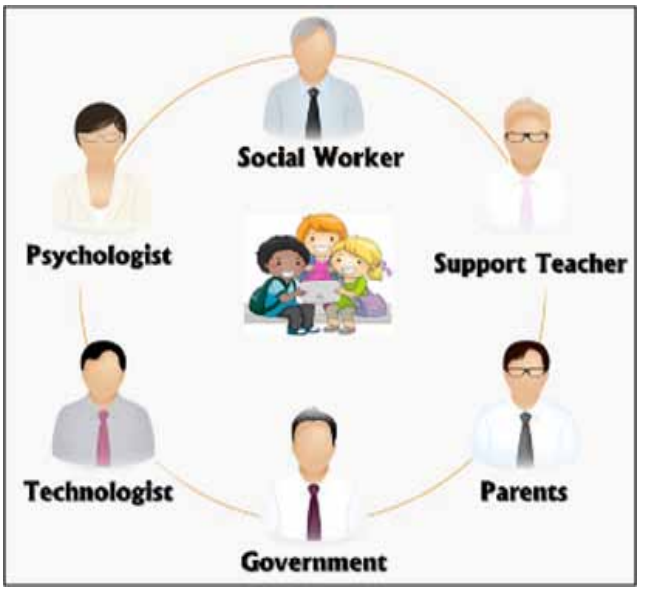
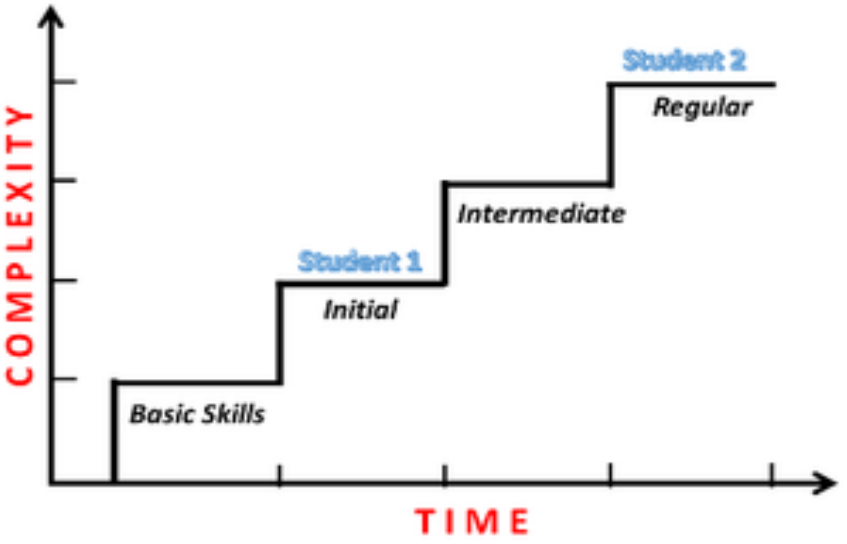


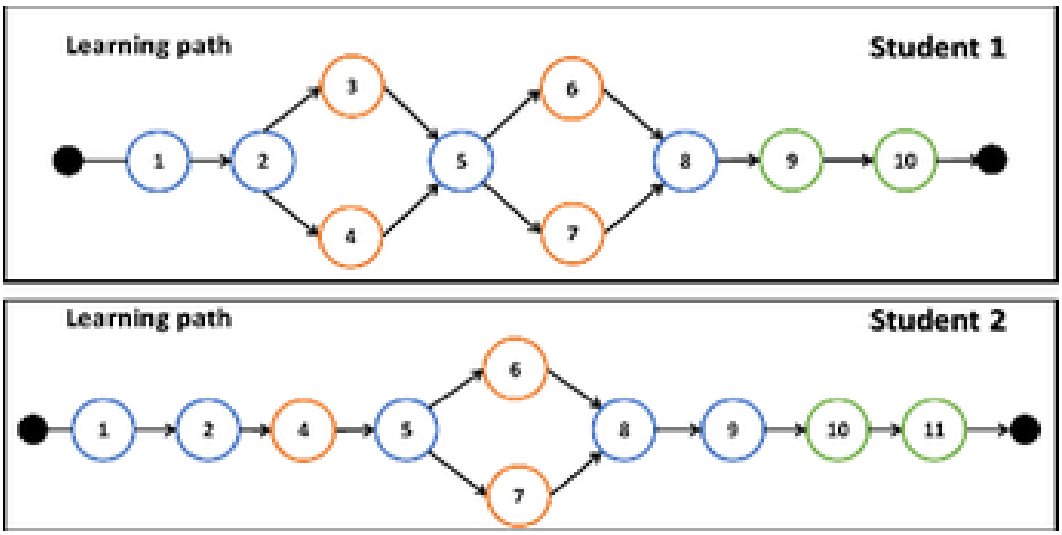
Figure 11. Levels of learning problems in basic mathematics of students 1 and 2



For student 1 on the learning path of Figure 12 (top), the knowledge of sizes, geometric figures and recognition of digits and numbers are incorporated, but in turn, can also perform in parallel the counting of objects and the resolution of algebraic additions to strengthen the numerical part. Once the learning objects were consumed, users' usability and user experience surveys were conducted to learn the feedback needed to develop more specific mobile applications in the following iterations.

The Figure 12 (bottom) shows the educational resources that can be granted to mitigate the problem of arithmetic operations such as multiplication, addition, subtraction, multiplication and division, to get the resolution of problems raised and finally the resolution of fractions problems.

Figure 12. Learning paths for Student 1 and 2



6.5. Use of Educational Resources

This stage of architecture is really the implementation of applications and educational resources in the learning community (USAER), which used the composition of services that include educational resources according to the profiles of students, during this exercise Support teachers, regular education teachers or parents, as appropriate, lowered the learning objects and the composition of services to use the applications, through the surveys feedback was obtained that helps to improve both the learning paths, The composition of services and educational resources, improving the specific techniques of delivery for each of the students of the learning community mentioned above.

6.6. Composition of Services

The composition of services is a variant of the use of educational resources, where learning objects (services of our architecture) can be composed of two or more educational resources. In our case study, we used more than two mobile applications and educational resources extra to mitigate a single problematic of basic math that children presented, in other words, the composition of services can help to mitigate the problem of a skill, attacking it from various points through the variety of mobile applications.

6.7. Repositories

Once the educational resources were identified and the specific profiles of the 2 children with the help of the multidisciplinary group were identified, the educational resources contained in the mobile applications for mathematics were classified, these educational resources were labeled in a way that would help to mitigate the specific problem of mathematical abilities and that converts to services can identify and use according to the weights obtained by the multidisciplinary group. This was performed through the use of learning paths designed by the specialists in inclusive education that make up the multidisciplinary group.

After each child has used each of the learning objects recommended by the specialists, tests of usability and user experience were conducted, where the conclusions were positive but there were still recommendations for modification by the multidisciplinary group to improve the objects of learning.

6.8. Infrastructure

The infrastructure used in this case study were two computers as ways of access to the repositories to extract educational resources and as a query of user profiles, three electronic tablets with operating system “Android” and finally had access to the network through an internet provider with a bandwidth of 10 Mb/s.

6.9. Content Providers

According to the specialist, they were oriented towards the use of applications developed until now by development groups of the Autonomous University of Aguascalientes and the resources found on the official website of Google Play (Google, 2015), by which we can say that the providers now active are the public institutions and social organizations, among them are all those people who develop individually for social use.

7. CONCLUSION

Current work presents the use of an architectural model in order to help people with basic math problems. Through the use of the architectural model proposed, some members of USAER community was provided with learning objects using the employment specifications suggested by a multidisciplinary group through learning paths. These learning paths can help to organize and manage learning objects in a specific way and those were stored in repositories and distributed through services,

these services were distributed to two students showing an advance in the development of specific basic mathematical skills to each one of the children in the learning communities, in addition to the provided feedback by children through the use of learning objects as the multidisciplinary group.

Thanks to this work, it was also possible to verify the importance of technology as an educational tool, as long as it is guided by a multidisciplinary group that helps guide through learning paths and through the use of in the previous architecture, we can verify the importance of making technological developments (learning objects) according to the communities learning needs, like USAER, as well as the importance of feedback to multidisciplinary groups which facilitates that little by little they are developed by products more specific to the learning communities.

As future work, we intend to implement a digital ecosystem for children with mild learning problems in basic math, with other learning communities and including different content providers. Another issue is the development educational resources through software production lines and agile methods, taking into account the characteristics suggested by the multidisciplinary group, in order to have a greater impact results to mitigate the problem in learning basic mathematics.

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