Virtual learning environment for children with disabilities: a proposal based on MOODLE and content management with Over the Top (OTT) technology

Kevin Calle-Urgiléz*, Ma. Fernanda Mena-Salcedo*, Yaroslava Robles-Bykbaev*†, Vladimir Robles-Bykbaev*, Hernán Tenorio Carpio‡

*GI-IATa, Cátedra UNESCO Tecnologías de apoyo para la Inclusión Educativa, Universidad Politécnica Salesiana, Cuenca, Ecuador

†Grupo de Investigación en Terapia Celular y Medicina Regenerativa (TCMR), Departamento de Medicina, PROTERM, MODES, Universidad de A Coruña, España

‡Instituto de Parálisis Cerebral del Azuay (IPCA), Cuenca, Ecuador

Email: {kcalleu,mmenas}@est.ups.edu.ec, yaroslava.robles.bykbaev@udc.es, vrobles@ups.edu.ec,nan.58@hotmail.com

***Abstract*—Nowadays the Learning Management Systems (LMS) are widely used in all educational levels (schools, colleges and universities). MOODLE, one of the most used platforms, had been registered in more than 76000 sites over 230 countries. However, the World Health Organization (WHO) claims that 5.1 percent of children worldwide have a disability. In the same line, one third of all children not in primary school are those that present disabilities. This situation becomes more complicated in developing countries due the lack of educational services and tools adapted to needs of children with disabilities as well as the poor connectivity of centers of special education to online resources. For these reasons, in this paper we present an approach to address three important aspects Virtual Learning Environments (VLE) as support tools for special education in Ecuador: the connectivity problems of centers of special education, the lack of online resources for children with disabilities, and the lack of tools to analyze the children and teachers perception about educational contents stored in VLE. Our proposal uses the Over The Top (OTT) technology and performs statistical and data mining analysis to provide support for decision making. The approach has been put to test with 26 children with different types of disabilities and has reached encouraging results.**

I. Introduction

Nowadays, there is no consensus on the number of children with disabilities worldwide. However, some of the most widely accepted estimates indicate that about 93 million children (1 out of 20 children under 14 years) live with a severe or moderate disability [1] (other studies indicate a number of 200 million children [2]).

In the same way, the World Health Organization (WHO) estimates that children with disabilities are less likely to complete school: 61% of boys and 53% of girls without disabilities complete it, while 51% of boys and 42% of girls with disabilities are able to complete their studies [1].

This situation becomes more complex in developing countries, since there are no educational support environments (both traditional and virtual) suitable to respond to the needs of this historically excluded population. Similarly, several special education centers do not have adequate connectivity resources to access Internet or with appropriate assistive technologies so that children can perform their learning/training tasks in a normal way.

On the other hand, despite the fact that today there are virtual environments that allow supporting the teaching-learning process, the majority of them are not adequate to deal with three problems that we consider critical (in addition to the lack of staff or resources):

- Limited access to the Internet that still is present today by several special education centers. In these cases, despite that today almost all institutions are considered to have adequate access to the Internet, in countries such as Ecuador there are still problems related to connectivity, bandwidth or even lack of total Internet connection.
- Existence of virtual/digital educational materials that are not adequately adapted to work with children with various types of disabilities such as cerebral palsy, intellectual disability, Down Syndrome, etc.
- Lack of tools to analyze the impact and the acceptance level of materials and virtual learning environments in children with disabilities and special education professionals.

For these reasons, this article presents a proposal that seeks to provide support not only in the provision of virtual educational contents for centers specialized in care and education of children with disabilities, but also to establish criteria to analyze the impact of these resources on the teaching-learning process. Our proposal combines the following technologies and tools:

- Over the top (OTT) technology that allows the platform

to automatically adjust videos and images so that the material can be properly delivered to education centers.
- A proposal of analyzer based on data mining techniques that allows visualizing through dendrograms how children and educators perceive the contents and services offered through the virtual platform. In the same way, the Principal Component Analysis (PCA) [3] technique is used to present different alternatives of clusters considering the most relevant attributes of the children profiles and their perceptions about the system.
- Validation and statistical modeling of the tools that allow data collection (surveys, forms, etc.).

The rest of the paper is organized as follows. In Section 2 we describe some of the most recent researches related with our proposal. The general systems architecture as well as the data mining services provided by the system are detailed in Section 3. The experimentation processes carried out in the Instituto de Parálisis Cerebral del Azuay *IPCA* (Cuenca, Ecuador) with 26 children with different types of disabilities is presented in Section 4. Finally, the conclusions and future work are presented in Section 5.

II. Related work

In the last decade, have been developed different proposals that implement technological solutions to provide support to special education through virtual learning environments. In this section we will review some recent researches that are related with our proposal. Considering that nowadays Moodle is one of most used LMS (7600 websites over 230 countries) our proposal as well as this section is focused on those projects and researches that implement this LMS as a solution to provide e-learning [4].

In [5], a design of MoodleAcc educational platform for people with different types of disabilities (motor, hearing, visual), is presented. The educational contents are personalized for each student so that the use of the virtual tool is fully exploited, their work is based on the development of metamodels with the objective of creating specific systems for specific needs. Educational platforms focused on special education need to be designed differently than common education platforms.

Currently, several institutions and educational centers have developed virtual learning platforms that facilitate the cooperative education. A proposed work in [6] presents a tool for Moodle course designers to include content for visually impaired people, this work is based on the idea of sharing the multimedia content through audios or printable letters in braille so that the user captures the teaching purpose.

The platform that we developed besides working on computers can run in any mobile device with the only condition to have an Internet connection, because children are very attracted to working on mobile devices. In [7], a mobile application called *Picaa* is created, designed for children with special educational needs. Picaa tries to cover the main areas of the learning process such as exploration, association, puzzle and classification. We cover the majority of the educational domains in our project, as indicated in Figure 1.

The analysis of the students' data allows the optimization of the contents that are distributed so that the student feels satisfaction while navigating the educative page. In [8], a data analysis is detailed, analyzing the time the user takes between each action while interacting in the Moodle platform. According to this project, the data show a probability density function (PDF) that can be analyzed to provide useful feed back to the course designer.

Another effective way to optimize the course creation is to analyze the needs of each student as proposed in [9], where each student's curriculum is customized using artificial intelligence to map the results. Tests show that it is more convenient to customize educational content per student than to use the same educational resource for all students.

III. Proposed approach

Our proposal is aimed in providing a complete set of educational contents for children with different types of disabilities. In the same way, our proposal has been designed bearing in mind the connectivity limitations that present several centers of special education in Ecuador. On those grounds, our system combines the OTT technology with support decision modules. As can be seen in Figure 1, the main system layers and components are described below:

- The educational contents stored in **MOODLE** virtual learning environment (https://moodle.org/) [10]. Through this open platform it is possible to access to all contents using different devices such as desktop computers, smartphones, tablets, etc.
- In the layer **OTT-education environment** the system includes 3 modules to provide contents such as: **courses** (according to special education curriculum and the children needs), special designed **tests** to evaluate the children progress in each special education area, serious **games** (soup of letters, hanged, etc.), and **multimedia** content (videos, images, animations, texts, etc.). In this layer are provided two plugins that automatically perform a **video transcoding** and **image compression** to adjust the video and image sizes according to the bandwidth of each center of special education that uses the platform.
- Currently our platform includes 10 **areas of knowledge**: academic domain, community domain, human body, sensoperceptions, recreational domain, domestic domain, basic education, gross motor skills, fine motor skills, and communication. Each of these areas covers a wide set of concepts such as civic values, spatio-temporal notions, colors, geometric figures, foods, family, personal hygiene, among many others (Figure 2).
- The **data analysis layer** consists of 3 modules that provide teachers with support for decision making: **analysis of students' tests**, **analysis of teacher's needs**, and **content creation module** (currently under development). These modules use data mining techniques and PCA to automatically create groups of students according to different criteria (more details in the next subsection).

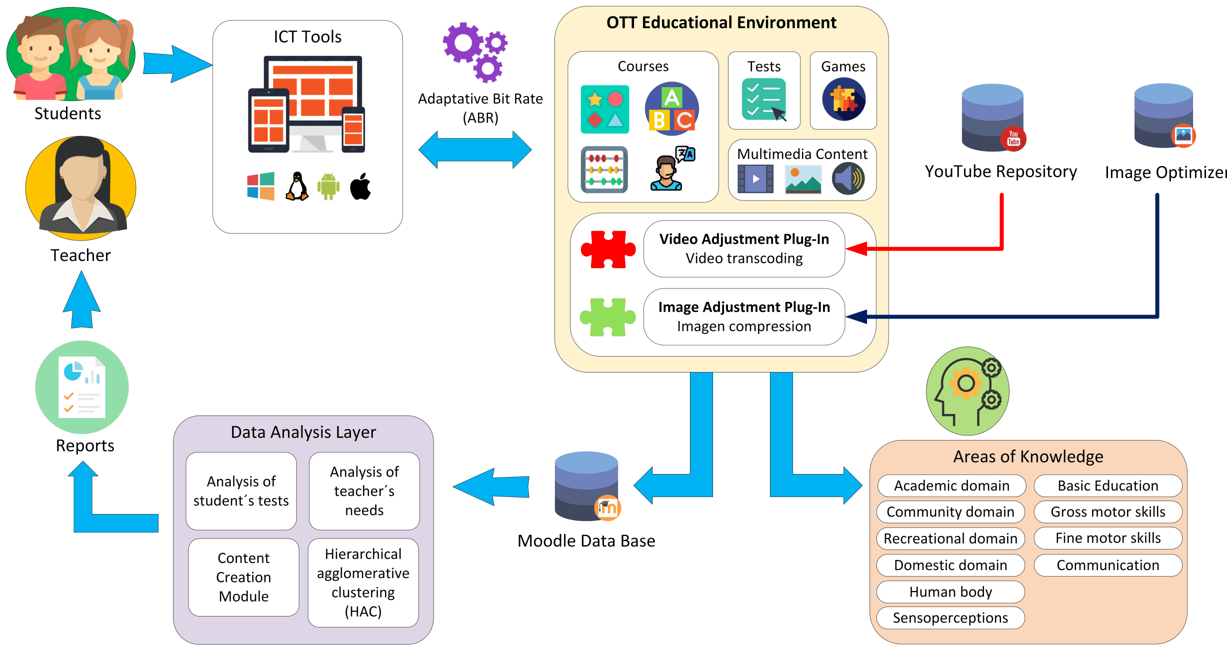

Fig. 1. General system architecture and the main modules and functionalities developed to support the virtual learning of children with disabilities.

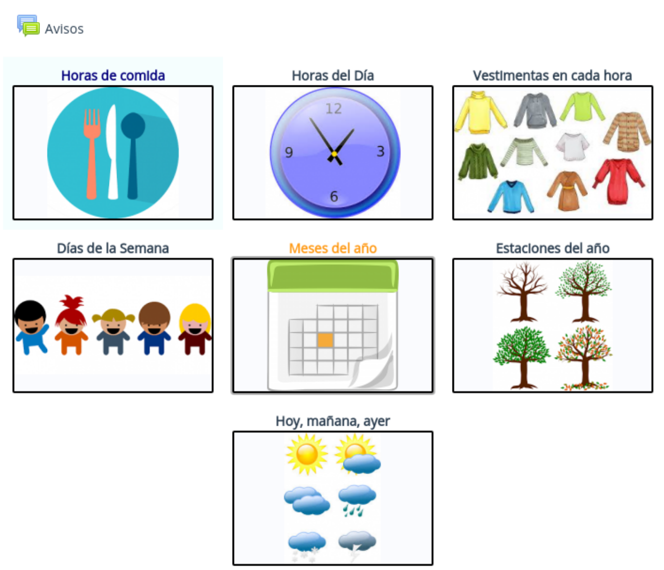

Fig. 2. A screen capture of spatio-temporal notions menu in MOODLE. As we can see, the platform provides 7 topics in this area: feeding hours, hours of the day, seasons, etc.

A. Children and teachers perceptions about the platform: a statistically validated survey

In order to determine the children and teachers perceptions about our platform we have designed a survey consisting of 83 variables defined in Likert scale [11]. The survey is organized in two main blocks: a first one to determine teachers perceptions and a second one to determine the childrens perceptions about the platform. In general, the blocks consider several aspects such as: videos (loading speed, quality, etc.), platform characteristics (impact, usefulness, pertinence for special education, etc.), educational contents, images (loading speed, quality, etc.), among many others.

Our survey has achieved a score of **0.9811918** in the Cronbach alpha coefficient [12].“Alpha was developed by Lee Cronbach in 1951 to provide a measure of the internal consistency of a test or scale; it is expressed as a number between 0 and 1. Internal consistency describes the extent to which all the items in a test measure the same concept or construct and hence it is connected to the inter-relatedness of the items within the test” [13].

B. A module based on data mining and PCA analysis to support decision making

With the aim of supporting the decision making we developed a module that automatically generates groups of children according to their profile and perceptions about the platform and its contents. To accomplish this objective, we propose the following descriptor to represent each child profile (p):

$$\vec{p} = \{A, G, D, IP, SP, C, R\} \tag{1}$$

Where:

- A represents the child’s age and is defined in the range $[3, 29]$ given that some of the participants are youth with several disabilities.
- G is the child’s gender.
- D represents the disability that child presents and is defined in the range $[physical, intellectual, physical + intellectual, autism, cerebralpalsy, language]$
- IP is the childs perception about the images and is measured in the Likert scale (1=very low quality, 2=low

quality,3=enough quality, 4=good quality and 5=good quality).

- SP is the child's perception about the sounds and is measured in the Likert scale (1=very low quality, 2=low quality,3=enough quality, 4=good quality and 5=good quality)
- C represents the child's level of concentration that was measured by therapists and is defined in the Likert scale (1=very low , 2=low, 3=enough, 4=high, and 5=very high).
- R represents the child's level of retention that was measured by therapists and is defined in the Likert scale (1=very low, 2=low, 3=enough, 4=high, and 5=very high).

With these profiles descriptors we have used the Hierarchical Agglomerative Clustering (HAC) approach [14] to generate clusters of children according to their platform contents perceptions. With this objective is proposed the distance metric described in Eq. 2:

$$\begin{aligned} d(p_i, pj) = w_1 \cdot |fs(A(p_i)) - fs(A(p_j))| \\ + w_2 \cdot |G(p_i) - G(p_j)| + w_3 \cdot |D(p_i) - D(p_j)| \\ + w_4 \cdot \sqrt{\sum_{up \in \vec{UP}} (up(p_i) - up(p_j))^2} \end{aligned} \quad (2)$$

Where:

- $d(p_i, pj)$ represents the distance between the profiles p_i and p_j.
- $w_1, w_2, \ldots, w_4$ are the weights used to indicate the relevance of each profile attribute used in the metric.
- $fs()$ is a formula that applies a factor scale to patient's age ($A(p_i)$). This factor is defined as follows:

$$v = 1 - \frac{max(\vec{a}) - A(p_i)}{max(\vec{a}) - min(\vec{a})}$$

  Where v is the new value defined in range $[0, 1]$ and $\vec{a}$ is the vector of patients ages.
- $G(p_i)$ and $D(p_i)$ are the gender and disability of the child profile p_i. The disability is represented with numbers defined in range $[0, N]$ (where N is the total number of disabilities).
- $\vec{UP}$ is a vector of children perceptions about the platform. Each perception is defined in Likert scale.

Furthermore, we have used the PCA technique to extract the most relevant features of the descriptor presented above. This step allows us using descriptors with more features (for example an anamnesis record can contain more than 40 variables) to feed a neural network or another type of machine learning tool.

IV. Experiment and Preliminary Results

With the aim of validating our proposal, we have worked with 26 children and youth with different types of disabilities. In this section we present the most relevant results related with childrens perceptions about the platform. The group of participants has the following characteristics:

- The group is distributed in 16 boys and 10 girls.
- The participants age ranges from 3 to 29 years.
- In general terms, the distribution of disabilities is the following: physical disability (12), intellectual (8), physical+intellectual (1), autism spectrum disorders (1), cerebral palsy (3) and language disorders (1).

In Figure 3 we can see a dendrogram generated using Eq. 2. As it can be seen, if we cut the dendrogram at distance of 0.8 is possible to get 4 groups. This information is useful for teachers of special education given that if we analyze the group constituted by children with ids 7, 20, 6, 22, 2, 4 and 26 we can note that all children present physical disability. In the same way, is possible to change the weight w_4 and the system will provide groups of children that have similar perceptions about quality of images, videos or other variables.

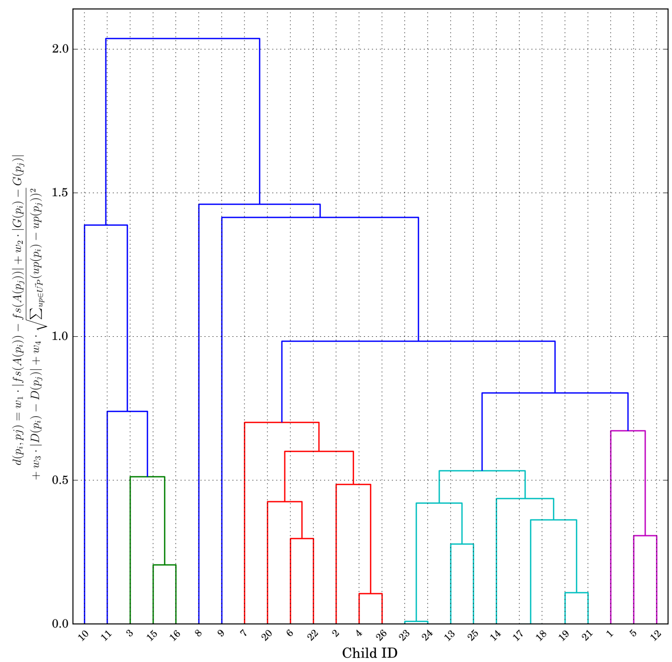

Fig. 3. Dendrogram generated from the Eq. 2.

On the other hand, in Figure 4 is depicted a dendrogram generated with the 3 principal components of the children profiles. As it can be seen, the dendrogram shows groups formed by different profiles.

Furthermore, the statistical module implemented in the platform has generated the results depicted in Figures 5 and 6. Bellow we describe the main results and findings:

The top left panel of the Figure 5 shows the types of disabilities of the children assisting to the IPCA institution distributed according to gender and age. Physical disability prevails in both, girls (4) and boys (6), representing a total of 10 children with this condition. These children used the "Educational Platform to Improve the Basic Education Level of Children with disability". The intellectual disability follows the physical one, in frequency, with a total of 7 children (3 girls and 4 boys).

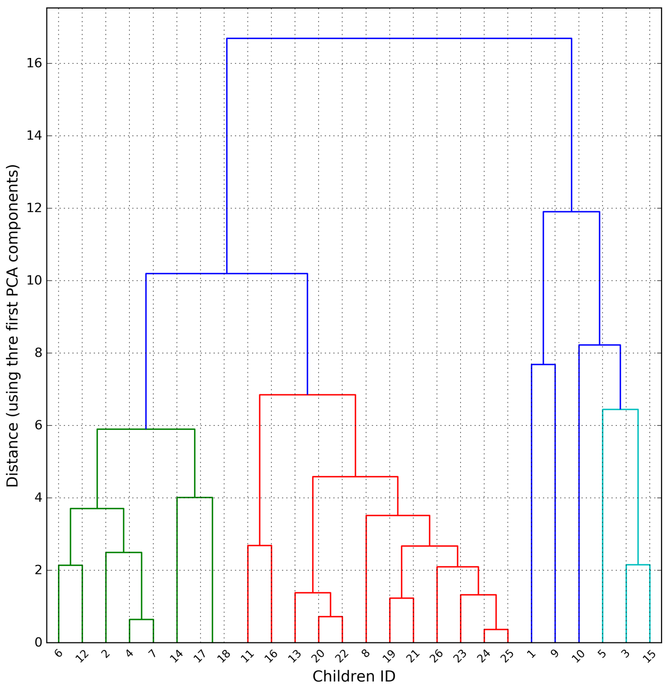

Fig. 4. Dendrogram generated from the Eq. 2 and using the 3 most relevant PCA components.

In the top right panel, we can see that most children with multi-disability and whose age ranges from 3 to 25 years, surveyed through IPCA educational tutors, perceive that the speed with which the images of the platform are loaded is “sufficient” and “fast”. Moreover, two boys, aged 18 and 21 years old, with physical and intellectual disability respectively, and a 29-year-old girl (with intellectual disability) perceive the speed of loading videos as “absolutely fast”.

In the bottom left panel, the same perception phenomenon is produced as in the upper right panel, but this time, the perception is about the speed with which the videos are loaded onto the platform. We also observed that the majority of children between the ages of 3 and 25 perceive that the speed with which the images of the platform are loaded is “sufficient” and “fast”. One 18-year-old boy with physical disability, and two girls, aged 15 and 29 years old, both with intellectual disabilities, perceive as ”absolutely fast” the speed at which the videos are loaded.

Analyzing these results, it can be pointed out that speed in general terms, according to the tutors who observed the childrens perceptions while using the educational platform, is adequate for the multi-disability level that these children present.

In the Figure 6, we can see that the perception about the “sensation of using the educational platform” of children between 3 to 29 years old with disabilities is high, since the majority of children indicated that it is “pleasant”, “absolutely nice” and “very nice”.

In the upper right panel, the perception of the children about the colors of the screen, we can observe that majority of tutors denoted that the platform’s screen colors are “very nice” and “pleasant” for the children.

In the lower left panel, the perception of children with multi-disability on the usefulness of the educational contents of the platform is positive, indicating that they are “absolutely useful”, “very useful” and “useful”.

Finally, in the upper right panel, the perception of children with multi-disability between 3 and 39 years old about the quality of the videos was mostly ”excellent”, “very good” and “good”, ergo, the perception on this item is positive.

Then, it can be thought, that the items which were statistically analyzed through the tutors about the perceptions of these children about: loading speed of images, loading speed of videos and loading speed of educational activities, are “enough” and “fast”, so it means that the objective of improving the users’ QoE is reached.

V. Conclusions

This work had a great impact on the education of children with different levels of disabilities as evidenced by the tests carried out. The acceptance that we had by teachers and students reveal the need of virtual tools of this type encouraging the use of ICT in the special teaching/learning process.

The OTT multimedia content distribution is a turning point in the benefits of this project because it increases the user’s QoE when using the virtual environment. The results of the carried-out surveys show that the user has a good experience navigating in this platform.

This analysis can be concluded by highlighting that the perception of the children from the IPCA institute about the use sensation of the platform, screen colors, usefulness of the educational platform, attention when using the platform and videos quality, is adequate, since their values are between 4 and 5 in the Likert Scale of the educational platform for children with disability, meaning that the perception is positive. This obtained information can be used by the tutors to adjust the multimedia educational contents according to the childrens necessities.

As lines of future work we propose the following:

- To develop a recommender module aimed on assembling educational reinforcement activities for house according to different educational areas mentioned above.
- To design a module to automatically create evaluation activities for each child, considering their profile (chronological age, cognitive age, communication disorders, disability, etc.).

Acknowledgment

This work was funded by the Cátedra UNESCO Tecnologías de Apoyo para la Inclusión Educativa and the research project “Sistemas Inteligentes de Soporte a la Educación Especial (SINSAE V5)” of the Universidad Politécnica Salesiana. We would like to thank the support provided by the Instituto de Parálisis Cerebral del Azuay (IPCA).

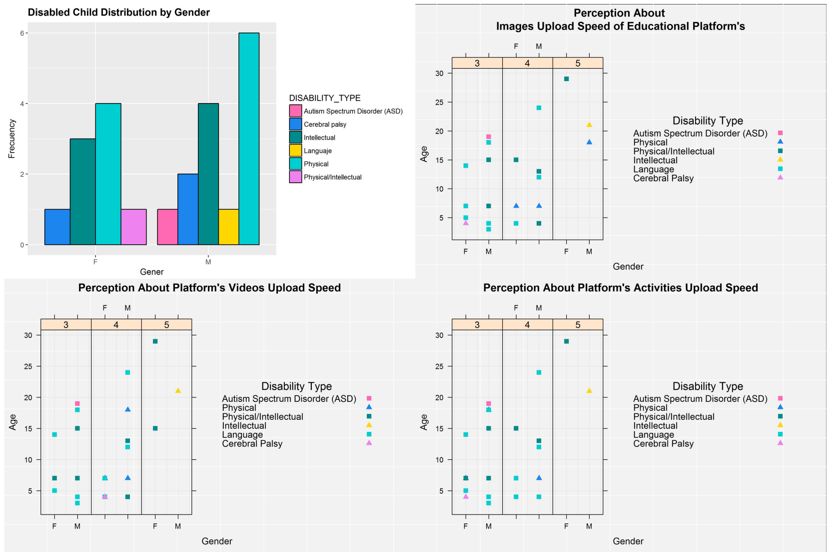

Fig. 5. Children gender distribution and their perceptions about platform speed to load videos, images and activities.

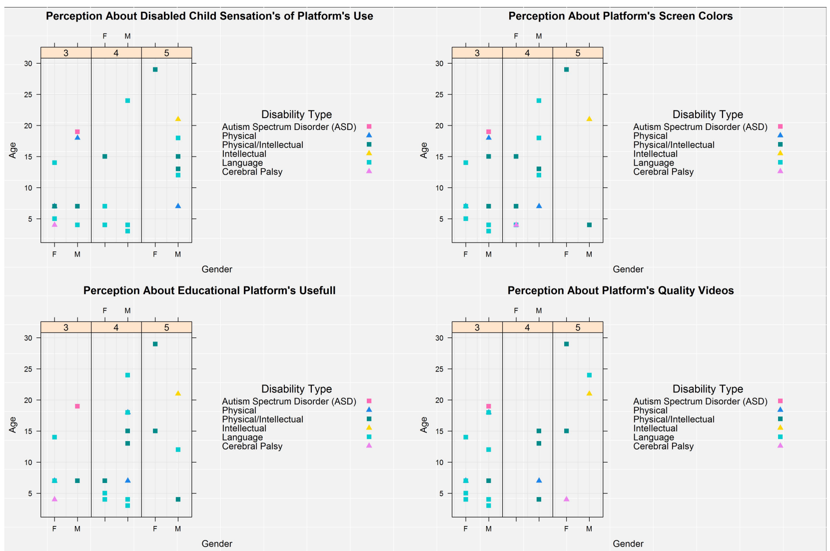

Fig. 6. Children's perceptions about the following platform features: colors, ease of use, video quality and usefulness.

References

[1] UNICEF, "Estado mundial de la infancia: Niñas y niños con discapacidad," *Fondo de las Naciones Unidas para la Infancia*, 2013.

[2] ——, "Monitoring child disability in developing countries results from the multiple indicator cluster surveys," *Nueva York: United Nations Childrens Fund Division of Policy and Practice*, 2008.

[3] H. Chowdry, C. Crawford, L. Dearden, A. Goodman, and A. Vignoles, "Widening participation in higher education: analysis using linked administrative data," *Journal of the Royal Statistical Society: Series A (Statistics in Society)*, vol. 176, no. 2, pp. 431–457, 2013.

[4] V. Casadei, L. Zaina, E. Pinheiro, and T. Granollers, "Accessibility evaluation of design patterns on moodle mobile," in *Brazilian Symposium on Computers in Education (Simpósio Brasileiro de Informática na Educação-SBIE)*, vol. 27, no. 1, 2016, p. 688.

[5] M. Laabidi, M. Jemni, L. J. B. Ayed, H. B. Brahim, and A. B. Jemaa, "Learning technologies for people with disabilities," *Journal of King Saud University - Computer and Information Sciences*, vol. 26, no. 1, pp. 29 – 45, 2014, current Advances in Digital Learning Technologies. [Online]. Available: http://www.sciencedirect.com/science/article/pii/S1319157813000347

[6] V. R. Ulbricht, T. Vanzin, M. Amaral, V. Vilarouco, S. R. P. de Quevedo, L. A. M. Moretto, and A. R. Flores, "A tool to facilitate including accessible content in moodle to the person with visual impairment," *Procedia Computer Science*, vol. 14, pp. 138 – 147, 2012, proceedings of the 4th International Conference on Software Development for Enhancing Accessibility and Fighting Info-exclusion (DSAI 2012). [Online]. Available: http://www.sciencedirect.com/science/article/pii/S1877050912007788

[7] Á. Fernández-López, M. J. Rodríguez-Fórtiz, M. L. Rodríguez-Almendros, and M. J. Martínez-Segura, "Mobile learning technology based on ios devices to support students with special education needs," *Computers & Education*, vol. 61, pp. 77–90, 2013.

[8] A. Charitopoulos, M. Rangoussi, and D. Koulouriotis, "Educational data mining and data analysis for optimal learning content management: Applied in moodle for undergraduate engineering studies," pp. 990–998, April 2017.

[9] V. Caputi and A. Garrido, "Student-oriented planning of e-learning contents for moodle," *Journal of Network and Computer*

Applications, vol. 53, pp. 115 – 127, 2015. [Online]. Available: http://www.sciencedirect.com/science/article/pii/S108480451500065X

[10] A. J. V. Gómez, “Accesibilidad e inclusión educativa en contextos de educación especial,” *Flor de Ceibo*, p. 89, 2014.

[11] J. A. Gliem and R. R. Gliem, “Calculating, interpreting, and reporting cronbachs alpha reliability coefficient for likert-type scales.” Midwest Research-to-Practice Conference in Adult, Continuing, and Community Education, 2003.

[12] S. A. Domínguez-Lara, “¿ por qué es importante reportar los intervalos de confianza del coeficiente alfa de cronbach?” *Revista Latinoamericana de Ciencias Sociales, Niñez y Juventud*, vol. 13, no. 2, pp. 1326–1328, 2015.

[13] M. Tavakol and R. Dennick, “Making sense of cronbach’s alpha,” *International journal of medical education*, vol. 2, p. 53, 2011.

[14] A. Shepitsen, J. Gemmell, B. Mobasher, and R. Burke, “Personalized recommendation in social tagging systems using hierarchical clustering,” in *Proceedings of the 2008 ACM conference on Recommender systems*. ACM, 2008, pp. 259–266.