

ROBOSTEAMSEN Taxonomy to Support Teachers in Fostering STEAM Education for Students with Intellectual and Developmental Disabilities

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Abstract. In today's society, teachers must train the best future professionals in educational institutions to facilitate the proper progress of our society. Some of these teachers educate individuals with intellectual or developmental disabilities, and promoting their employability requires providing them access to the so-called STEAM disciplines. However, teaching STEAM to students with disabilities is challenging and often hindered by a lack of resources, time, or training in the use of tools and methodologies. The ROBOSTEAMSEN, an Erasmus+ European project, addresses this issue by educating teachers in the use of active learning methodologies and robotics to foster STEAM education. A key aspect of this project is the classification of methodological and technological resources that teachers can use. To this end, the project developed a taxonomy that allows the classification of resources to address various challenges associated with Intellectual and Developmental Disabilities (IDD). The taxonomy includes the characterization of different aspects such as possible disabilities and their levels, the student's profile, their preferences, difficulties, learning objectives, and educational activities. This paper presents this taxonomy, discusses its various elements and demonstrates its implementation.

Keywords: Intellectual and Developmental Disabilities, IDD, STEAM, Robotics, Active Learning Methodologies.

1 Introduction

Current technological society requires the best-prepared professionals to succeed. To achieve this, one approach is to facilitate the development of 21st-century skills [1].

The cultivation of these skills has been linked to STEAM (Science, Technology, Engineering, Arts, and Mathematics) education. Research indicates that these disciplines not only enhance workforce performance but also increase a nation's capacity for innovation [2, 3]. This underscores the importance of fostering interest in STEAM among young learners and integrating STEAM principles into contemporary educational curricula. Several projects and initiatives have addressed this topic, such as TACCLE3 [4] and RoboSTEAM [5]. However, education must be inclusive, and this includes STEAM education. In this context, projects such as W-STEM [6, 7] and CreaSTEAM [8] have examined the potential of STEAM for inclusive education for specific groups. Nevertheless, these projects do not focus on people with disabilities, a highly relevant demographic for our society that tends to experience high levels of unemployment.

For this demographic, STEAM education can be critical. However, accessing STEAM disciplines for individuals with disabilities is frequently challenging due to several factors: the pervasive underestimation of their capabilities in STEAM fields, an inaccessible STEAM curriculum, and the limitations educators face in supporting inclusive learning [9, 10]. To address these challenges, effective strategies are necessary. Robotics, for instance, has emerged as a promising tool for advancing STEAM education. However, the critical element is not merely the use of robotics but its adaptation for individuals with disabilities and various types of disabilities [11]. This necessitates equipping experts and educators with specialized robotic resources, methodologies, and tools tailored to diverse disabilities.

RoboSTEAMSEN is an Erasmus+ European project that aims to address this by supporting Special Education Teachers of students with Intellectual and Developmental Disabilities (IDD) by providing them with specialized tools and strategies to foster STEAM. This requires understanding common IDD, their characteristics, and personalizing learning with robotics and active learning methods for a wide array of Special Educational Needs (SEN) teaching activities [12].

Workpackage 2 (WP2) of the project aims to adapt resources, methodologies, and tools for individuals with Intellectual and Developmental Disabilities (IDD) to equip them with the knowledge necessary for integrating robotics and active learning techniques across various IDDs. To provide this comprehensive set of tools, it is essential to classify them according to different criteria, for which a taxonomy has been defined.

The remainder of the paper is structured as follows: Section 2 briefly describes WP2. Section 3 presents the taxonomy and its implementation, while Section 4 discusses a use case. Finally, some conclusions are drawn about the impact of this taxonomy on the project.

2 Context Description

The RoboSTEAMSEN Project is organized into five work packages, which include the adaptation of resources and methodologies for individuals with IDD, the training of SEN teachers in how to utilize these resources, the development of a community of practice, and the dissemination of the project's results. [13].

The taxonomy definition is included into ROBOSTEAMSEN WP2. It is intended to provide individuals with the necessary knowledge to integrate robotics and active learning techniques for various IDD. Its key objectives include:

- O1. Evaluate the educational needs of students with IDD by considering factors such as disability types, severity levels, age, and educational progression.
- O2. Develop a user model that utilizes this categorization to improve personalized learning for these students.
- O3. Assemble and organize a collection of robotics resources and active learning strategies for STEAM (Science, Technology, Engineering, Arts, and Mathematics) education, aligning them with the defined classification.
- O4. Offer guidance for educators on customizing robotics and methodological tools for students with disabilities in STEAM subjects.
- O5. Test and validate the user model and categorization framework by creating tailored intervention strategies utilizing robotics for students with various disabilities.

To achieve these objectives several tasks have been proposed:

- WP2.T1. Analysis and extraction of key features for classifying students with IDD: The goal of this task is to identify the main factors to be considered in the taxonomy.
- WP2.T2. Definition of a taxonomy for classifying students with disabilities based on WP2.T1 features: This involves identifying different taxa and validating their use in student classification.
- WP2.T3. Definition of a user model for personalizing learning in STEAM: This model will consider the various disciplines and student characteristics.
- WP2.T4. Compilation of robotics and methodological resources and instruments: These resources will be used to tailor interventions based on the user model.
- WP2.T5. Definition of case scenarios for adapting interventions: This task will utilize resources from WP2.T4, the user model from WP2.T3, and the taxonomy from WP2.T2.
- WP3.T6. Validation of the case scenarios, taxonomy, and user model.
- WP3.T7. Definition of guides and samples for personalizing STEAM education for students with IDD, based on previous results.
- WP3.T8. Transnational Project Meeting.

Given these objectives and tasks, the expected deliverables include:

- A Comprehensive Taxonomy: This taxonomy will describe the characteristics of students with IDD, allowing for the categorization of educational resources based on disability type, severity, and other relevant criteria.

- **A User Model Derived from the Taxonomy:** This model will encapsulate the specific needs of students, informed by their disabilities as outlined by the taxonomy. It aims to provide a detailed representation of each student's requirements.
- **A Collection of STEAM Education Resources and Tools:** An assembly of robotics solutions and methodological instruments will be compiled and categorized using the taxonomy. This collection will form the basis for creating personalized intervention adaptations in STEAM disciplines for students with various disabilities.
- **Guidance for Implementing the User Model and Resource Repository:** Manuals will be developed to assist teachers in utilizing the user model to accurately profile students and subsequently access the repository for resources that align with the students' needs. This guidance is crucial for adapting interventions in practical educational settings.
- **Prototype Interventions for Common IDD Scenarios:** These examples will be tailored to the most common situations encountered among students with IDD within specific STEAM disciplines, demonstrating how the taxonomy and resources can be applied to meet diverse educational needs.

All deliverables will undergo thorough evaluation by experts in the field and be field-tested by educators in participating schools, ensuring their effectiveness and applicability in enhancing the learning experiences of students with IDD.

3 The taxonomy

As described above one of the key elements for WP2 and for the project is the taxonomy. The taxonomy should be the base for the user model so it should facilitate the characterization of a disability with its levels and features (in green in Fig. 1). The profile of the student taking into account the disability (in blue), the user data and preferences (in red), the issues related with the learning activities (in blue) and those related with the resource and special needs of the student (in yellow). Fig 1 shows a UML diagram to describe the main categories of the taxonomy and the relationships among taxa of included into them.

Taking into account this solution the elements to instantiate were the following.

- **IDD:** only three IDDs were considered Autism Spectrum Disorder, Attention Deficit Hyperactivity Disorder (ADHD), Learning disability (to define)
- **Level:** The level or levels of the disability.
- **Features:** IDD features depending on the level of the IDD. This was done using DSM features [14]. For instance, for ADHD a feature could be “deficiencies in non-verbal communicative behaviors used in social interaction”.
- **Difficulty:** associated to one or several features related with education, “difficulty to work as a team”.
- **Educational area:** In which it is included the difficulty. For instance: “Collaborative competences” taking into account the classification provided by Polloway [15] and those included into DSM-5.

The researchers have completed by now the taxa for the two disabilities ASD in the three different possible levels and ADHD. Based on these disabilities and in the possible resources several learning objectives were proposed including also the “Others” option to include a new one. A sample of difficulties for the area “learning and cognitive challenges” could be: “Time management”; “Sharing a common focus”; “Cognitive Abilities”; “Individualized learning strategies accommodations”; “Has difficulty organizing tasks and activities”; “Avoid tasks that require sustained mental effort”, etc. And a sample of possible learning objectives for the difficulties related with the disabilities previously mentioned would be: “Emphasize self-reliance”; “Promote self-management”; “Engage in abstract thinking”; “Symbolic Thought”; “Effective Studying”, etc.

3.2 Taxonomy Implementation

Regarding the implementation of the taxonomy, it forms the core of the user model. For the end-user, it will be represented as a search and classification tool. The center of the user model is the data model; however, the complexity is quite high. A student could have a different IDD at various levels, with specific features and associated difficulties. Additionally, it is necessary to consider comorbidity, meaning a user could have multiple disabilities. To facilitate readability, we will include only the data model for the resources classification tool in this section (Fig 2).

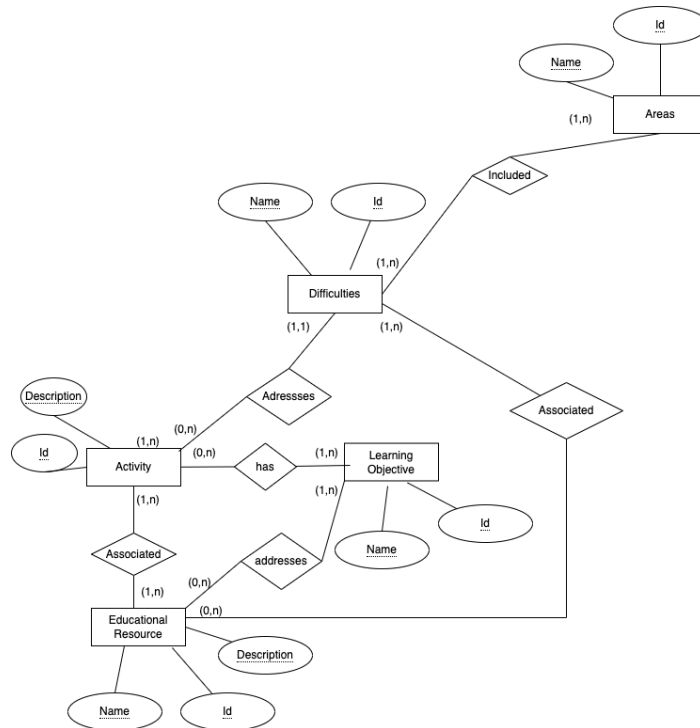


Fig. 2. Entity Relationship Diagram

This tool must account for the difficulty or difficulties addressed by an educational resource, associated with an educational area, the activity in which it will be applied, and the learning objectives of the activity. It is important to note that a resource can be used for several difficulties and vice versa, but an activity is defined for a specific difficulty.

The resources classification is done through a web system (Fig 3), where the partnership is compiling a set of 100 resources, 50 methodological and 50 technological (a sample can be seen in Fig 4), which can be used in educational activities to create the learning plan for a user with a specific profile.

Home / Resources / New

New

Partners' Institution
University of Leon

Resource Name *

Description of Resources Event *
Please add a description of the resource. It can be done through a link.

Sample of use in education with students with IDD *

Fig. 3. Form for the compilation of resources

Pepper Robot

Resource description

<https://www.aldebaran.com/en/pepper>

Sample of use in education with students with IDD

<https://www.frontiersin.org/journals/psychology/articles/10.3389/fpsyg.2023.1232177/full>

Describe an activity in which it can be applied

Improving cognitive and social skills

Difficulties to which it could be applied

Emotional Regulation, Executive Functioning and Flexibility

- Avoidance behavior or meltdowns

Emotional Regulation, Social Communication Challenges

- Literal interpretation of language and abstractions

Learning Objectives

- Organization of time
- Learning Engineering concepts
- Learning Maths concepts
- Learning Science concepts
- Learning Technology concepts

Fig. 4. Compiled resource sample

4 Use case

As a complete example of the resource classification, this section presents a methodological resource using the defined templates and the difficulties and objectives described for ASD and ADHD. The resource considered is the use of Challenge-Based Learning (CBL) for IDD students. Challenge-Based Learning [16] is a well-known active learning methodology suitable for use with IDD students, and there are application examples in this context [17]. Regarding the activity, the idea is for IDD students to develop challenges while integrated into groups of regular students. The objectives are to improve social behavioral interactions and enhance STEAM competencies. As shown in the user model, the resource can be applied to several difficulties. We have included an example considering the implemented taxa.

Table 4. Resource Description

Resource Name: Challenge Based learning
Resource description: https://www.challengebasedlearning.org/
Sample of use in education with students with IDD: https://onlinelibrary.wiley.com/doi/abs/10.1002/cae.22354
Activity: Teaching Science to students through the completion of challenges in groups.
Difficulties: Problems initiating and maintaining conversations, Solitary Activities and Limited Engagement in meetings, Understanding social norms and rules Non interactive play, Literal interpretation of language and abstractions Delayed development or unusual speech patterns, Organization and planning task and activities, Time management, Sharing a common focus, Making/Keeping friends, Cooperative Interaction, Reading, writing or maths challenges.
Learning Objective: Improve social behavioral interaction, improve STEAM competences.

5 Conclusions

The ROBOSTEAMSEN project addresses a critical need in modern education by providing teachers with the tools and methodologies to effectively integrate STEAM education for students with IDD. By developing a comprehensive taxonomy, the project enables the classification of educational resources tailored to various disabilities and their specific challenges. This taxonomy is central to creating personalized learning experiences that leverage robotics and active learning methodologies.

The successful implementation of this taxonomy, as demonstrated through case studies and examples, highlights its potential to enhance the educational outcomes for IDD students. By systematically addressing the diverse needs and difficulties associated with different disabilities, the project fosters an inclusive learning environment where all students can thrive in STEAM disciplines.

Moreover, the project's focus on collaboration among educational institutions and technical partners ensures that the developed resources and methodologies are both

practical and sustainable. The inclusion of various stakeholders, including teachers, researchers, and policymakers, further amplifies the project's impact, paving the way for future educational strategies and policies that prioritize inclusivity and accessibility.

In conclusion, the ROBOSTEAMSEN project exemplifies the potential of innovative educational approaches in transforming the learning experiences of students with IDD. The project's outcomes not only provide immediate benefits to the participating institutions but also set a precedent for broader educational reforms that embrace diversity and promote equal opportunities in STEAM education.

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References

1. García-Peñalvo, F.J., Mendes, J.A.: Exploring the computational thinking effects in pre-university education. *Computers in Human Behavior* 80, 407-411 (2018)
2. García-Peñalvo, F.J., Reimann, D., Maday, C.: Introducing Coding and Computational Thinking in the Schools: The TACCLE 3 – Coding Project Experience. In: Khine, M.S. (ed.) *Computational Thinking in the STEM Disciplines: Foundations and Research Highlights*, pp. 213-226. Springer International Publishing, Cham (2018).
3. European-Commission/EACEA/Eurydice: The European Higher Education Area in 2018: Bologna Process Implementation Report., Publications Office of the European Union https://eacea.ec.europa.eu/national-policies/eurydice/sites/eurydice/files/bologna_internet_0.pdf (2018).
4. TACCLE 3: Coding Erasmus + Project website, <https://goo.gl/f4QZUA>, last accessed
5. Conde, M.Á., Rodríguez-Sedano, F.J., Fernández-Llamas, C., Ramos, M.J.C., Jesus, M.D., Celis, S., Gonçalves, J., Lima, J., Reimann, D., Jormanainen, I., Paavilainen, J., García-Peñalvo, F.J.: RoboSTEAM Project: Integrating STEAM and Computational Thinking Development by Using Robotics and Physical Devices. In: Francisco, J.G.-P. (ed.) *Information Technology Trends for a Global and Interdisciplinary Research Community*, pp. 157-174. IGI Global, Hershey, PA, USA (2021).
6. García-Peñalvo, F.J.: Women and STEM disciplines in Latin America: The W-STEM European Project. *Journal of Information Technology Research* 12, v-viii (2019)
7. García-Holgado, A., García-Peñalvo, F.J.: A model for bridging the gender gap in STEM in higher education institutions. *Women in STEM in Higher Education: Good Practices of Attraction, Access and Retainment in Higher Education*, pp. 1-19. Springer Nature Singapore Singapore (2022).
8. Amo, D., García-Holgado, A., Fonseca, D., García-Peñalvo, F.J., Jurado, E., Olivella, R., Maffeo, G., Yiđit, Ö., Hofmann, C., Quass, K., Sevinç, G., Keskin, Y.: CreaSTEAM. Towards the improvement of diversity gaps through the compilation of projects, best practices and STEAM-Lab spaces. Ninth International Conference on Technological Ecosystems for Enhancing Multiculturality (TEEM'21), pp. 92–97. Association for Computing Machinery, Barcelona, Spain <https://doi.org/10.1145/3486011.3486426> (2021).

9. Lamptey, D.-L., Cagliostro, E., Srikanthan, D., Hong, S., Dief, S., Lindsay, S.: Assessing the Impact of an Adapted Robotics Programme on Interest in Science, Technology, Engineering and Mathematics (STEM) among Children with Disabilities. *International Journal of Disability, Development and Education* 68, 62-77 (2021)
10. Bargerhuff, M.E., Cowan, H., Kirch, S.A.: Working toward equitable opportunities for science students with disabilities: Using professional development and technology. *Disability and Rehabilitation: Assistive Technology* 5, 125-135 (2010)
11. Benitti, F.B.V.: Exploring the educational potential of robotics in schools: A systematic review. *Computers & Education* 58, 978-988 (2012)
12. Training SEN teachers to use robotics for fostering STEAM and develop computational thinking, <https://robosteamsen.eu/>, last accessed 23/03/2024.
13. Conde, M.Á., Rodríguez-Sedano, F.J., García-Peñalvo, F.J., Gonçalves, J., Jormanainen, I., Anzanello, A., Alves, J.F.R., Hernández, R.F., Ailincăi, A.A.: ROBOSTEAMSEN Project - Training SEN Teachers to Use Robotics for Fostering STEAM and Develop Computational Thinking. 2024 International Symposium on Computers in Education (SIIE), pp. 1-6. IEEE, A Coruña, Spain (2024).
14. Association, A.P.: Diagnostic and Statistical Manual of Mental Disorders: DSM-5-TR. American Psychiatric Association Publishing (2022).
15. Polloway, E.A., Bouck, E.C., Patton, J.R., Lubin, J.: Intellectual and developmental disabilities. *Handbook of special education*, pp. 265-285. Routledge (2017).
16. Apple-Inc: Challenge Based Learning - Take action and make a difference. US http://ali.apple.com/cbl/global/files/CBL_Paper.pdf (2009).
17. Conde, M.Á., Rodríguez-Sedano, F.J., Fernández-Llamas, C., Gonçalves, J., Lima, J., García-Peñalvo, F.J.: Fostering STEAM through Challenge Based Learning, Robotics and Physical Devices: A systematic mapping literature review. *Computer Application in Engineering Education* 29, 46-65 (2021)