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SECTION: ARTICLES

Teaching technical drawing to a student with visual impairment: use of a tactile tool integrated into a competency-based model[1]

Enseñanza de dibujo técnico a estudiante con discapacidad visual: uso de herramienta táctil integrado a la metodología de formación por competencias

Ensino de desenho técnico a estudante com deficiência visual: uso de ferramenta tátil integrada à metodologia de formação por competências

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ABSTRACT

This study[6] presents the development and application of a tactile didactic-pedagogical tool aimed at teaching technical drawing to a student with visual impairment. The research was

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conducted within the context of a foundational engineering course at a higher education institution, aiming to provide learning and assessment experiences aligned with the principles of competency-based education. The methodology involved coordination between instructors and the psychopedagogical support team to mediate practical activities, supported by a tool developed based on studies of tactile perception, spatial visualization, and graphical representation. The results indicated that the tool enabled the student to autonomously develop the skills to read, interpret, and execute standardized graphical representations. The study highlights the potential of the proposed solution to enhance inclusive practices in technical education and to broaden discussion on inclusion and equity in higher education.

Keywords: educational inclusion; visual impairment; technical drawing; competency-based education; assistive technology.

RESUMEN

Este trabajo presenta el desarrollo y la aplicación de una herramienta didáctico-pedagógica táctil orientada a la enseñanza del dibujo técnico a un estudiante con discapacidad visual. La investigación se llevó a cabo en el contexto de una asignatura del ciclo fundamental de Ingeniería de una institución de educación superior, con el objetivo de proporcionar experiencias de aprendizaje y evaluación alineadas con los principios de la enseñanza por competencias. La metodología contempló la articulación entre docentes y el equipo psicopedagógico para mediar actividades prácticas, conducidas con el apoyo de una herramienta desarrollada a partir de estudios sobre percepción táctil, visualización espacial y representación gráfica. Los resultados indicaron que el recurso permitió al estudiante desarrollar, con autonomía, habilidades de lectura, interpretación y ejecución de representaciones gráficas normalizadas. La investigación evidencia el potencial de la solución propuesta para fortalecer prácticas inclusivas en la enseñanza de asignaturas técnicas y ampliar el debate sobre inclusión y equidad en la educación superior.

Palabras clave: inclusión educativa; discapacidad visual; dibujo técnico; enseñanza por competencias; tecnología asistiva.

RESUMO

Este trabalho apresenta o desenvolvimento e a aplicação de uma ferramenta didático-pedagógica tátil voltada ao ensino de desenho técnico a um estudante com deficiência visual. A pesquisa foi conduzida no contexto de uma disciplina do ciclo básico dos cursos de Engenharia de uma instituição de ensino superior, com o objetivo de proporcionar experiências de aprendizagem e avaliação alinhadas aos princípios do ensino por competências. A metodologia contemplou a articulação entre docentes e equipe psicopedagógica para a mediação de atividades práticas, conduzidas com o apoio de uma ferramenta desenvolvida com base em estudos sobre percepção tátil, visualização espacial e representação gráfica. Os resultados indicaram que o recurso permitiu ao estudante desenvolver, com autonomia, habilidades de leitura, interpretação e execução de representações gráficas normatizadas. A pesquisa evidencia o potencial da solução proposta para fortalecer práticas inclusivas no ensino de disciplinas técnicas e ampliar o debate sobre inclusão e equidade no ensino superior.

Palavras-chave: inclusão educacional; deficiência visual; desenho técnico; ensino por competências; tecnologia assistiva.

INTRODUCTION

The Universal Declaration of Human Rights (1948) and the Salamanca Statement (1994) affirm that education is a universal and inalienable right of every citizen. In Brazil, this premise is reinforced by the Law of Guidelines and Bases of National Education (1996), which ensures the inclusion of all Brazilians in basic and higher education institutions, regardless of their physical, intellectual, social, or emotional conditions. According to Dardes (2010), this harmonization between regulatory frameworks strengthens inclusive education, regardless of factors such as ethnicity, religion, socioeconomic status, or disabilities.

Leijen, Arcidiacono, and Baucal (2021) highlight that, in Brazil, awareness of the aforementioned topic is broad and consolidated, constituting a driving force for numerous initiatives to implement inclusive didactic-pedagogical strategies at various educational levels. Regarding the implementation of inclusion in the educational context, the works of Dalla Déa and Rocha (2016) and Sá and Dalla Déa (2020) present fundamental contributions. The researchers point out that, from basic to higher education, inclusive practice is not just about inserting the student into the academic environment and giving them all the support they need to remain in school. According to the authors mentioned, it is also necessary to develop strategies and methods entirely dedicated to adequately meeting the general and specific needs of students with special needs. This means that, in the classroom, these actions must converge and be aligned to ensure that all students, without distinction, develop socio-emotional and technical skills compatible with the training required in their respective courses. Thus, it is clear that it is necessary to provide students with special needs with an equitable school experience, both in learning experiences and in evaluation processes.

Regarding the process of inclusion of people with disabilities in the academic environment, an interesting finding on the subject can be appreciated in the work of Almeida et al. (2017). The educators highlight an important and valuable aspect for reflections in all sectors of education: “[...] school content prioritizes the use of vision in all areas of knowledge, thus hindering its adaptation to sensory methods that facilitate the learning of visually impaired students" (ibid., p. 2).

The quotation above reveals the urgent need to develop strategies that enable the inclusion of visually impaired people in both basic and higher education, so that individuals with low vision or blindness can experience the same learning opportunities offered to students without visual impairments. Therefore, assistive technologies (i.e., resources, equipment, or systems whose main objective is to maintain or improve the functioning and autonomy of people with disabilities) have gained prominence as instruments promoting inclusion (Brazil, 2015; Khasnabis; Mirza; Maclachlan, 2015). According to McNicholl et al. (2019), such technologies have the potential to improve functional performance, reduce activity limitations, promote social inclusion, and increase participation in education, the labor market, and civic life.

Therefore, this study aims to present the didactic-pedagogical practices and strategies used in the Technical Drawing discipline, offered in the first-year engineering programs at a private Higher Education Institution (HEI), to facilitate the inclusion of a student with bilateral blindness. Specifically, it seeks to show that the pedagogical solutions adopted were able to provide learning and assessment experiences equivalent to those of other regular students, even in a teaching model based on competencies and not solely on content. It is worth noting that the activities proposed by the Technical Drawing course aim to provide students with the resources to develop the ability to technically read, interpret, and represent parts and assemblies through orthographic projections in accordance with current technical standards. Further details about the course's structure can be found in Todaro and Lebrão (2022b, 2024).

THEORETICAL FRAMEWORK

Before discussing strategies for developing standardized graphic representation skills in visually impaired students, it is fundamental to highlight the importance of technical drawing in Engineering. According to Resolution No. 1010/2005 of the Brazilian Federal Council of Engineering, Architecture, and Astronomy, knowledge of the execution, reading, and interpretation of two-dimensional and three-dimensional graphic representations, regulated by technical standards, is mandatory. Therefore, Higher Education Institutions must ensure that Engineering graduates are able to demonstrate graphic communication skills. Thus, university courses covering Technical Drawing, from the elementary level of graphic characterization to advanced topics used in Engineering projects, should encourage students to develop a graphic-visual language. Furthermore, the courses involved in this context must provide students with a repertoire to read, interpret, and record information in a way that allows them to (re)elaborate ideas in various professional situations. Therefore, within the scope of this work, Fucks' (2018) recommendations can be incorporated as a didactic-pedagogical strategy to include students with visual impairments in these courses, as can be seen in the following excerpt:

> The language of drawing makes it possible to conceive imagined, unreal projects, but also to create graphic or glyphic visual representations of real-world situations; allowing for the materialization of visual information that is not always possible for everyone to perceive through sight, as is the case with visually impaired people. In this circumstance, information abstracted from reality by others can be assimilated by the blind student through varied stimuli that reach other sensory organs, such as touch and hearing. In teaching, such stimuli can be appropriately guided by the teacher in order to mobilize attention and increase the interest of all students, being essential when it comes to including the blind student (Fucks, 2018, p. 4).

Given the importance of the cognitive development of engineering graduates, it is incumbent upon the teaching staff to possess knowledge and mastery of teaching and learning strategies aimed at students with disabilities. Therefore, regarding the strategies used by education professionals to facilitate the technical drawing learning for visually impaired students, the contributions of Almeida et al. (2016, 2017), Duarte (2004a, 2004b), and Fucks (2018) will be summarized below. These references are the main contributions present in the specific literature on inclusion in didactic situations involving standardized graphic representations.

Duarte's work (2004a) contains findings and discussions of great importance to understanding the process of mental image formation and acquisition of graphic language by blind school-age youngsters. In her work, the researcher reports the need to find alternatives to reproduce learning experiences based primarily on drawing practice for a visually impaired elementary school student. Although it does not concern technical drawing, the experience reported by the author is of paramount importance to the scope of this work. In seven interactions, called "moments" by Duarte (2004a), the researcher summarizes her own experience and contributes to the summarization of a sequence of activities. These tasks apply to elementary school students and can be used in higher education in an attempt to develop drawing skills equivalent to those developed in individuals without visual impairments.

> The first stage of the process requires the recognition of the object through tactile experience. [...] The second stage requires a directed action in which the child traces the edges and contours of the objects with their index finger (the most sensitive finger, the one used for reading Braille). [...] In the third stage, the figure is presented to the child, cut out of a plastic material. [...] In the fifth stage, the child makes the first attempt to draw the object translated into a geometric shape. [...] In the sixth stage, the child rereads and tactually identifies the figure of their own drawing. In the seventh and final stage among the main learning sequences, the child is encouraged to create representations of new objects using the same geometric figure (Duarte, 2004a, pp. 139-140).

Although the above-mentioned experiment was conducted with a student enrolled in a basic education course, Duarte (2004b) raises some very relevant considerations. According to the author, it is possible to construct a global notion of objects, using materials and methods that allow blind students to understand the edges of the parts and their "contour lines" tactilely, using sequential-temporal logic and no longer visual-spatial logic.

It is also relevant to highlight the experience of Kennedy (n.d. *apud* Duarte, 2004b), a researcher who reveals qualitative results that corroborated Duarte's (2004b) considerations. The author understands the "contour line" as a line that determines the surface edges of the object, that is, edges that define the limits of a part. According to Kennedy (n.d. *apud* Duarte, 2004b, p. 138), "[...] blind people, like sighted people, understand the notion of contour lines, the imaginary line that the edge of objects allows one to intuit". At this point, it is essential to reflect on these considerations and highlight that, in the case of technical drawing, the contour lines mentioned by the authors as non-existent lines are precisely those that allow a defined orthographic projection, for example. In the field of Engineering, such elements are called visible contour lines, that is, when the edge of a part is perceived as a boundary between two faces. The non-visible contour line is a standardized element that is used when there is a common boundary between two faces, but which is not seen by the professional in a given observation position (Miceli; Ferreira, 2010).

In addition, Almeida et al. (2016) followed a student with congenital blindness, who did not master the Braille system, in a Technical Drawing course applied to mining. To facilitate her learning, the researchers adapted drawing tools using modeling clay and interlocking blocks. Furthermore, tactile contrast elements and a modified scale ruler with textures and embossed markings were used in the learning experiences proposed by the educators. Similarly, Fucks (2018) developed pedagogical materials for a student with blindness in Architectural Drawing. The strategy included tactile boards made of plastic sheets with different textures and detailed verbal descriptions of the elements present, such as walls, pillars, and property boundaries. Thus, the student, accompanied by Fucks (2018), had access to accessible two-dimensional graphic representations.

Given the above, it is observed that the literature dedicated to teaching, learning, and assessment methodologies in the field of technical drawing for students with visual impairments is still scarce. The work of Eches (2023) corroborates this statement, since it points to just over twenty references on assistive technologies for the visually impaired, and yet only a fraction of this list applies to the context of this study. For this reason, the need was identified to investigate pedagogical practices that provide opportunities for the cognitive development of undergraduate engineering students in this context. Additionally, there is a noticeable lack of a structured methodology accompanied by a didactic-pedagogical tool capable of systematically integrating the teaching, learning, and assessment processes in the development of standardized graphic skills. Thus, this work seeks to offer the academic community a proposal that articulates good practices of teacher mediation with the principles of accessibility and equity in the teaching of technical drawing to students with visual impairments.

METHODOLOGY

The methodology adopted in this study is based on an iterative and collaborative communication practice between the instructors of the Technical Drawing course and the professionals of the Maua Student Support Program (MSSP). The MSSP's approach is described in detail by Mello, Caldeira, and da Matta (2022). This institutional collaboration was conceived as an interdisciplinary, transversal approach aimed at integrating pedagogical and psychopedagogical aspects. According to Gatti and Barreto (2009), such an initiative is essential for the professionals involved to understand the student's academic challenges from multiple perspectives. Furthermore, according to Batista, Vivas, and Nunes (2022), this favors the formulation of more effective inclusive strategies. Moreover, in accordance with the considerations of Mello, Caldeira, and da Matta (2024), this approach was used to identify strategies capable of keeping the student engaged in the course throughout its duration, ensuring active participation in the proposed activities and promoting autonomy so that, together with instructors, they can adjust the most appropriate resources to the learning process.

Based on the establishment of the aforementioned relationship, the adopted methodology stems directly from an institutional reflection guided by two main approaches: the demand for assertive pedagogical practices aimed at inclusion and the need to provide accessible teaching materials and methods. Based on these approaches, this work proceeds to describe the didactic-pedagogical tool developed to mediate the teaching-learning process of the student with visual impairment. Subsequently, the text discusses the systematization of the experiences lived throughout the classes and evaluations, guided by the principles of the competency-based teaching model proposed by Todaro and Lebrão (2024).

Development of the didactic-pedagogical tool

The development of the didactic-pedagogical tool was structured based on the experiences reported by Duarte (2004a, 2004b) and inspired by the methodology proposed by Almeida et al. (2016), duly adapted in accordance with the recommendations of Fucks (2018). Added to this is the recognition, already well established in the literature, that visually impaired people are capable of conveying the notion of unity in their drawings through a constructive synthesis of partial impressions (Lowenfeld, 1939). Based on this set of fundamentals, it was defined that the ideal tool for teachers responsible for mediating the teaching of Technical Drawing to visually impaired students should meet the following requisites:

- To be tactile enough to ensure the student's good sensory perception of visible and non-visible contours (Duarte, 2004a);

- To provide opportunities for the construction of drawings through sequential-temporal logic (Duarte, 2004b);

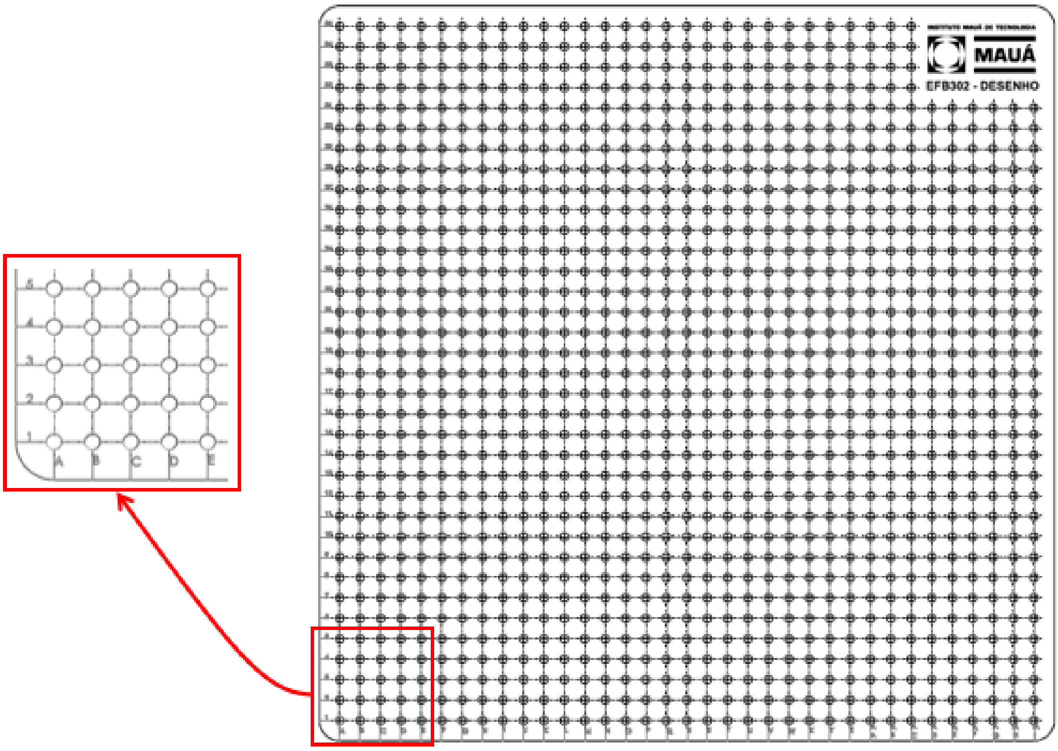
- To be simple and easy to handle, with special attention to the dimensions used (Almeida et al., 2017); and

- To contain clear elements of contrast (Fucks, 2018).

Complementary to the guidelines provided in the literature, the decision was made to develop a tool that would allow the student to define orthographic views with sensitivity and precision equivalent to those perceived by students without visual impairments. The intention is for the student to experience working technically with graphic representations, using the theoretical principles of projective technical drawing, and applying the standards that regulate graphic communication practices in Engineering.

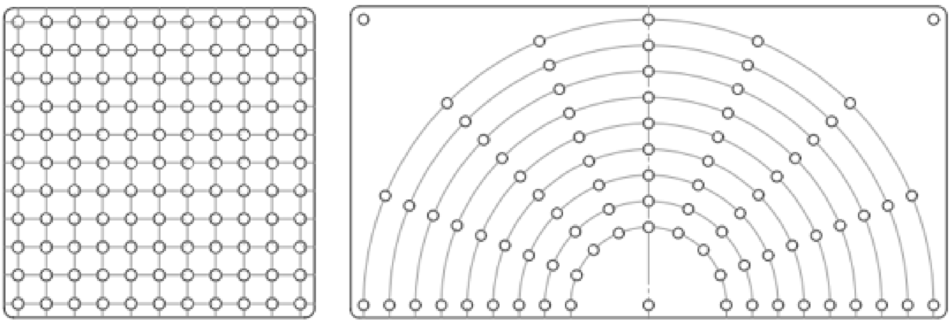
Based on this proposal, this work suggests the construction of functional tactile modules. These modules act as a didactic-pedagogical tool aimed at constructing orthographic views of low and medium complexity parts. The structure of the modules offers versatility of form and operates according to a geometric principle based on marking points on a Cartesian grid. To this end, a predominantly simple system was indicated, which considers the marking of Cartesian points by means of pins in a graduated grid. Each intersection between grid lines results in a hole designed for inserting a pin with sufficient interference to fix the end of one or more strings that will represent the contour lines of the parts. String-type cords were used to represent these lines. Figures 1 and 2 show the tactile modules constructed on this principle.

Figure 1 – Model of the main tactile module dedicated to the representation of orthographic views.



Source: prepared by the authors.

Figure 2 – Examples of possible submodules that can be used in the tactile module to represent parts with rectilinear (left) and circular (right) contours.



Source: prepared by the authors.

Specifically, Figure 1 shows the model of the tactile module that was produced in uniform panels of Medium Density Fiberboard (MDF), with dimensions of 540mm x 540mm x 9mm. These dimensions were defined after sensory-tactile perception tests carried out by the student. Highlighted in the same figure are the holes that represent the intersections between the lines of a grid, all of which are the same diameter, 6mm, and equally spaced at 15mm. It is worth noting that the tactile modules were designed to allow the attachment of submodules, that is, parts that allow the assembly to have greater versatility in the representation of parts without compromising the quality of representation of the shapes. Figure 2 shows examples of submodules produced to meet the orthographic projection representation of objects that have rectilinear and/or circular contours.

Regarding the principle of using the tool, it is important to inform that the pins play a central role in the process of defining the graphic representations: they represent the points that define the visible and non-visible contour lines of the part. For this reason, the basic principle of the tactile modules is that each pin represents at least one end of a given segment of string. Therefore, a pin clearly represents a vertex of the part, while the string is responsible for highlighting the visible and non-visible edges of the object being represented. In this case, stretched strings were chosen to represent visible edges, while twisted strings were chosen to symbolize non-visible contours. This characteristic provides tactile contrast to the student. In addition, the string has a second function in the sketching process: it allows the student to have the experience of drawing, that is, to reproduce, through sequential and temporal tactile movements, the handwriting produced on paper by sighted professionals.

Based on this strategy, it is possible to affirm that the undergraduate student will define the points and connect them in sequence using the strings, respecting the geometry of the part. Therefore, it was identified that it is necessary to make the object under study available to the student during the process of representing the orthographic projections. It is essential for the student to have knowledge about the definition within Cartesian coordinate systems to correctly use the material presented.

LEARNING EXPERIENCES

Regarding the inclusion of the visually impaired student in the Technical Drawing course, the teaching staff, supported by the MSSP professionals, indicated the student's participation in all in-person classes and the equal performance of assessment activities. Additionally, the mediators offered a strategic sequence of extracurricular support sessions. It was also suggested that, in the regular classroom, when convenient or at the student's request, an academic monitor would be available to describe details of the content mediated by the professor. Furthermore, the student would receive prior access to all material that would be presented in the in-person session.

It is worth noting that the classes taught were designed according to a format consistent with competency-based teaching and, therefore, included active learning models and used assessment, in various formats, as an auxiliary learning tool, as can be seen in the works of Todaro and Lebrão (2022a, 2022b, 2024). Thus, the student's inclusion was favored by active participation in discussions involving theoretical aspects of teamwork in problem-solving and by assessment in the same format as the other university students. However, the undergraduate student clearly had the support of professors and monitors of the course when the assessments required reflection on elements of parts and depended on the virtual learning environment to be carried out.

Regarding how the academic activities were conducted with the student during the extracurricular sessions, it is necessary to inform hat these activities aimed to prepare him for the practical tasks performed in the regular classroom. For the faculty, this support was considered an effective way to reinforce student inclusion, while recognizing the need to train the students in the use of the developed tools. From a psychopedagogical perspective, these actions served as an important link between pedagogical planning and student needs, promoting greater autonomy, engagement, and confidence in participating in regular activities.

During the extracurricular classes, the development of specific skills was stimulated in three main stages. Initially, in the words of a professor of the Technical Drawing course, the student received detailed descriptions of a particular part and was then asked to handle it to form his own impressions. In a way, the student was expected to develop specific spatial visualization from verbal descriptions, which was then confirmed by him through tactile perception. Secondly, the same parts described and handled were considered as examples for the reproduction of orthographic projections. At this stage, the orthographic views were provided, and the student had to identify the structures present in the tactile model and compare them with the part in their possession. Finally, in the third stage, different parts were considered, and the student was challenged to reproduce the orthographic views necessary for the correct description of the materials, according to the recommendations contained in technical standards.

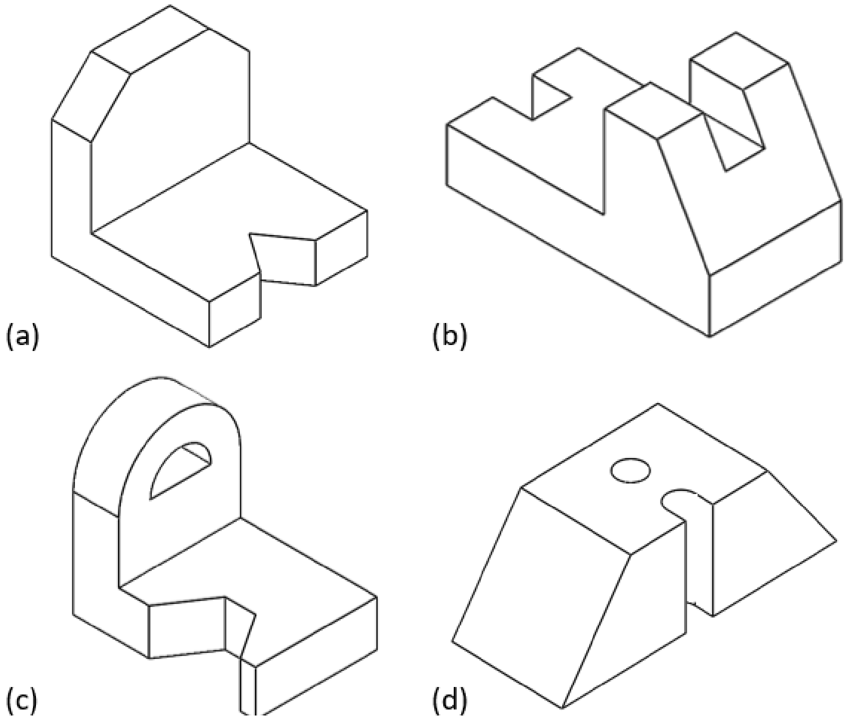
Table 1 summarizes the main objectives of each learning event proposed to the student throughout the course; in it, the acronym S.E. refers to the completion of activities in extracurricular sessions, while S.A. suggests the opportunity to reuse the tool in a regular classroom setting with the same objective. Figure 3 shows the parts used during the learning experiences proposed during the S.E. and S.A. sessions.

Table 1 – Summary of the learning activities proposed for the visually impaired student, mostly complementary to the regular classes on the graphic representation of parts and assemblies using orthographic views.

Event	Objective	Location
1	To map the tactile module for recognizing elements and shapes.	S.E.
2	To recognize parts from their orthographic views.	S.A.
3	To represent orthographic views using the tactile module.	S.E. e S.A.
4	To represent a real object using orthographic views and the tactile module.	S.A.

Source: prepared by the authors.

Figure 3 – Materials used in extracurricular sessions and in regular classroom lessons.



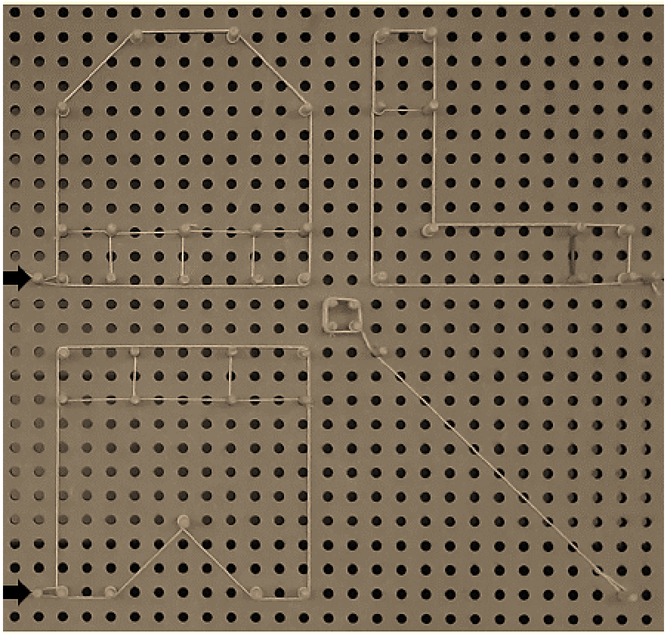
Source: prepared by the authors.

RESULTS

Event 1 in Table 1 was an important moment experienced by the student during the extracurricular sessions. The student was able to tactilely perceive that the material shown in Figure 1 can reproduce a conventional grid used in technical drawing. On this occasion, he was able to understand the analogy between the holes and the intersection points of the lines in a grid, as well as establish a significant association between the string and the contour lines. To represent or interpret a visible contour, a single stretched string was positioned between points marked by pins; for a non-visible contour line, two strings (of the same diameter as the string used for visible contours) were braided and positioned at the corresponding points.

It is worth noting that, when attaching the strings representing the part's contours, it was observed that the tracing of the visible contour lines could be done continuously, exactly as in freehand technical drawing, provided that the strings contoured the periphery of the pins rather than being fixed to the board by interference. Furthermore, to improve tactile perception and ensure a clearer presentation of the views, it was identified that extra pins could serve as starting points for the continuous sections of string. This approach is consistent with the study by Panotopoulou et al. (2020), whose authors emphasize that continuous and smoothly raised graphics facilitate the understanding of shapes and contours by tactile readers, provided that the fluidity of the line is preserved. Examples of the use of extra pins are indicated by the arrows in Figure 4, although they are also present in Figures 5 to 7.

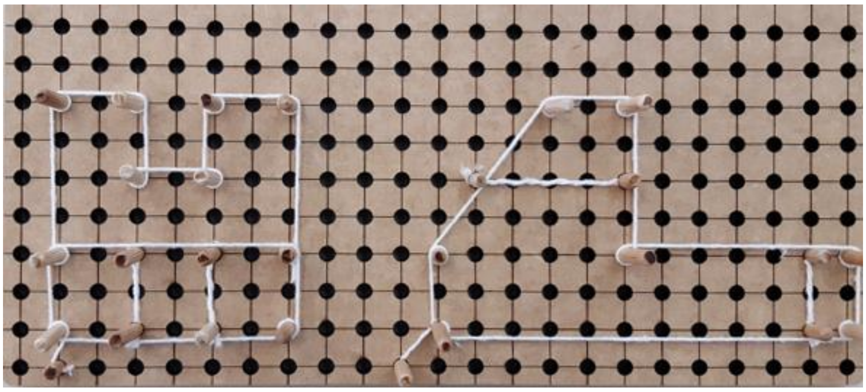
Figure 4 – Orthographic views reproduced on a tactile module for exploratory analysis.



Source: prepared by the authors.

Other important considerations to be highlighted as results of the tactile experience promoted during Event 1 were the definition of the best spacing between the module holes and the definition of the best tactile experience through the perception of the pin-board contrast. To obtain these parameters and, simultaneously, present the methodology for using the didactic-pedagogical tool, Event 2 included the recognition of distinct parts using orthographic projections as an experience. Figures 4 and 5, respectively, show the orthographic views of parts a) and b) displayed in Figure 3, constructed with different diameters for accommodating the pins and the distance between holes. The projections made for the parts in Figure 3 a) were reproduced on a tactile module with 8mm holes and 20mm spacing between them, while the orthographic views of the second part were generated on a module with 6mm pins accommodated in equally spaced holes at 15mm. The distances between the holes and the pin diameters suggested here were chosen based on sensory tests using cardboard. As a result, the 6mm-15mm and 8mm-20mm pin-distance combinations reflected the best preliminary tactile perceptions. In both cases, the visually impaired student received the two parts and the modules containing the orthographic views properly positioned. During the active practice, the student demonstrated a better tactile experience with the smaller-dimension module. For this reason, all modules and submodules were manufactured according to the dimensions recommended by the student. Thus, this opportunity for tool customization for the student remains aligned with the practices recommended by Rosenblum and Herzberg (2015).

Figure 5 – Orthographic views reproduced on a tactile module with 6mm holes equally spaced at 15mm intervals.

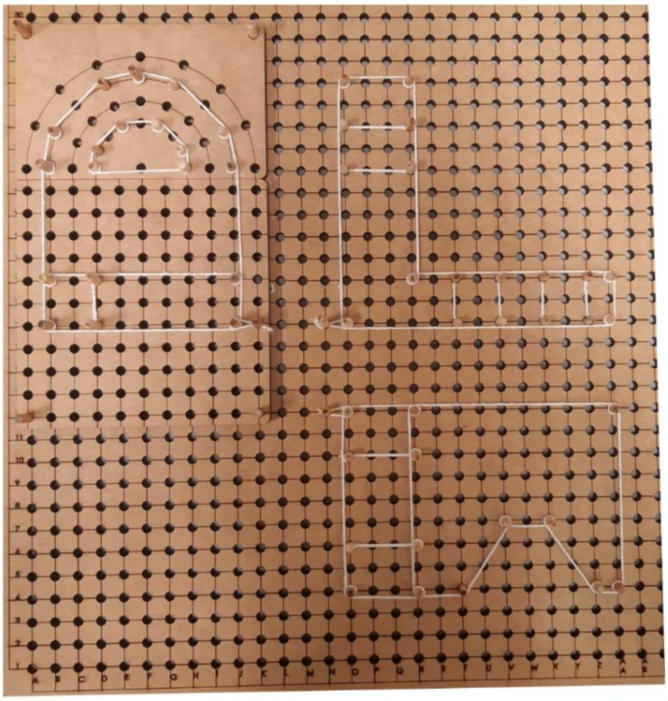


Source: prepared by the authors.

During the experiment, the student was able to easily discern the descriptive elements of the visible and non-visible contours of the indicated parts and successfully classified the objects via orthographic projections. Regarding Figure 4, the student also used the projection line to relate elements of the top and left side views, as expected, and had a good perception of the inclined surfaces that make up the part in Figure 3 a). In addition, using the empty holes as a reference, the student recognized the alignment between the orthographic views and the regularity of the distances between them, and also identified the contour lines that defined the limits of the part. This student perception was understood by the mediators and the PAAM professionals as an especially positive result provided by the tool. This response also occurred when the student investigated the module presented in Figure 5, although they demonstrated greater difficulty because they only received two orthographic views for identifying the part in Figure 3 b). Having the necessary tools for drawing the orthographic views, the visually impaired student had sufficient conditions to use the tactile module of their preference (6mm holes, spaced 15mm apart) to represent other parts through orthogonal projections. Event 3 included experiences carried out in regular and extracurricular sessions for this purpose, using the part shown in Figure 3 c). In this learning experience, the student demonstrated sufficient confidence to correctly define the contours of the part using the didactic-pedagogical tool. As a strategy, the student himself suggested marking the points based on the dimensions of the object, placed on the module in different interventions. When necessary, submodules were used as an additional reference for defining points on the main module. Examples of this occurred when the student sought information on the positioning of the vertices that defined the trapezoidal shape and the circular contours of the part. This strategy ensured consistent representation of the orthogonal views, despite the student's greater difficulty in precisely defining points in the main module. Additionally, it is worth noting that the strategy used in Event 3 remains consistent with the findings of Gomes et al. (2021), researchers who advocate for the direct manipulation of tactile models as favorable to the development of spatial and graphic skills by students with visual impairments. The result of Event 3 can be seen in Figure 6, which shows the orthographic views proposed by the student using submodules coupled to the tactile module in a regular classroom setting.

Given the above, it is evident that the student demonstrated the ability to read, interpret, and represent orthographic views of parts using the principles of technical drawing during Events 1 to 4. These experiences were part of a sequence of formative assessments conducted on time by the course, according to the competency-based teaching model proposed by Todaro and Lebrão (2022b, 2024), and therefore, the results shown here are obtained after receiving guided and meaningful feedback. Additionally, it is important to mention that the learning experiences undergone by the student were also provided to the other undergraduate students, with the exception of the use of the didactic-pedagogical tool. As a result of the summative assessment proposed by the course, Event 4 was entirely dedicated to the following purpose: to present the orthographic views of a real, non-didactic part, randomly chosen by lottery. The part selected by the student is shown in Figure 3 d) and is used as a fixing wedge for trapezoidal-shaped tiles, whose objective is to provide greater rigidity and prevent damage to the materials during assembly and maintenance processes (Hard, 2022).

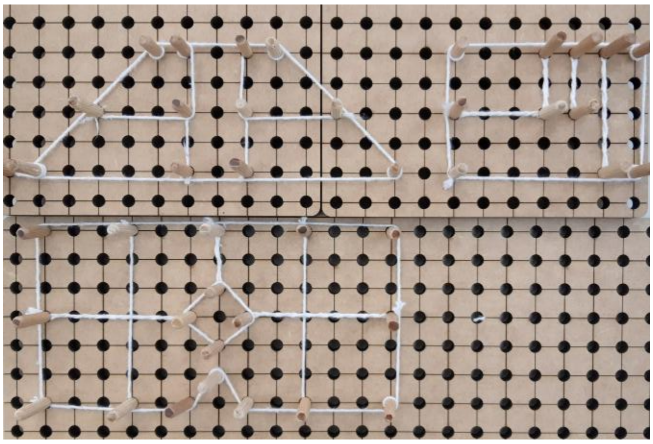
Figure 6 – Orthographic views produced by the student using the didactic-pedagogical tool.



Source: prepared by the authors.

Additionally, Figure 7 presents the front, top, and left side views suggested by the student as a way to represent the selected part. At the time, due to the small dimensions of the part, it was not appropriate to use submodules to represent the circular contours. For this reason, the mediator suggested that the student represent the circles using the points of tangency used for the freehand sketching of these geometric entities (inscribing the circle in a square with a side equivalent to the diameter), as suggested by Miceli and Ferreira (2010). However, although the circles were not visibly well-defined, the points marked by the student proved sufficient to describe the circular entities present in the part.

Figure 7 – Results of the summative assessment conducted on the tactile module of orthographic views.



Source: prepared by the authors.

FINAL CONSIDERATIONS

This work aimed to develop a didactic-pedagogical tool to support visually impaired students in reading, interpreting, and executing standardized graphic representations, in a manner analogous to that practiced by undergraduate students or professionals in the field of Engineering without visual impairment. More than just providing learning opportunities for the student, the tactile modules proved to be potentially capable of assisting visually impaired students in the execution of technical projective drawings and stimulating the development of spatial visualization, even in the face of blindness. Furthermore, the tool can facilitate the use of CAD software that has convenient accessibility features to reproduce orthographic projections of parts and assemblies using the same logic.

In general, it was observed that the student's disability did not impact the quality of his learning at university, nor did it prevent him from developing specific skills in Technical Drawing from the same learning experiences offered to other students and from being evaluated under the same criteria. It was also found that the assistance of teachers or tutors in regular classrooms or in extracurricular sessions is important to monitor the student's learning development; however, the need for support must be presented by the student. Thus, support can be understood as a moment of assistance in understanding shapes, requested by the student or indicated by the mediator. In this context, in addition to the availability of assistance, it was found that handling the parts discussed by the teacher significantly favors the construction of mental images. This phenomenon occurs especially when performed in sync with verbal mediation, which reinforces the fact that the visually impaired student further developed their spatial visualization during their training in the Technical Drawing course.

Regarding assistive technologies, the work shows that they can provide educational, psychological, and social benefits to any student who needs inclusive adaptations. However, both students and teachers should consider factors such as prior training in the use of these technologies and the need to adapt devices, which can favor engagement in the higher education environment. Future practices should focus on exploring the pedagogical potential of conventional resources adapted to different student profiles, further promoting inclusion initiatives.

Furthermore, although the results were promising, this study is limited by the fact that it is based on a single participant. Future research could seek to validate the tool with students with different types of visual impairments, as well as in other technical disciplines that require reading and standardized graphic representation.

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