PAPER • OPEN ACCESS

Geometry for design: approaches to the study of representation and dimension and their contributions to the modeling of phenomena

To cite this article: J P Acevedo-Rincon and C E Flórez-Pabón 2020 *J. Phys.: Conf. Ser.* **1674** 012009

Journal of Physics: Conference Series **1674** (2020) 012009 doi:10.1088/1742-6596/1674/1/012009

Geometry for design: approaches to the study of representation and dimension and their contributions to the modeling of phenomena

J P Acevedo-Rincon[1], **and C E Flórez-Pabón**[2]
[1] Instituto de Estudios en Educación, Universidad del Norte, Barranquilla, Colombia
[2] Conquiro, Universidad de Pamplona, Pamplona, Colombia

E-mail: pjacevedo@uninorte.edu.co, ceflorez@unipamplona.edu.co

Abstract. The difficulties of representation and understanding of the dimension are evident in the different educational levels. University education is no stranger to this situation. This communication was developed within the framework of the graphic design course. This course was designed under the use of specialized software in geometry, which was freely available and intuitive. It should be remembered that the adequate use of representations and attributes proper to the dimension aids in the representations of movement phenomena, as well as in the representations in force diagrams in the teaching of physics. This qualitative research aims to address aspects of representation and dimensionality from the description of some selected tasks of the group participants, who contrast the first representations, with their final activities. That is, these representations showed their evolution in construction, to the extent that the flat representations of objects in the portfolio were built in real dimensions, keeping the proportional relationship between its parts.

1. Introduction

Upon arrival at the university, in the first semester, the students of the graphic design program enroll in the geometry course and have the possibility to enroll in the basic mathematics course instead. However, most of them come to the geometry course with the thought of being "easier" than the other course because it is a way of escaping the "formalism of mathematics". By constituting a course that is taken in isolation, that is, it can be taken in any semester of the degree since it does not depend on the approval of others subjects, nor does it open the way to see other subjects that contain it as a requirement, this feeds the thought of being a “disjointed” course during the career. The teacher who takes this course must start from motivating their learning due to the implications that it has in the professional life of a graphic designer, which is not easy to see at the beginning of the course, where Euclidean geometry postulates to characterize shapes and attributes not allow to hook their attention. From the recognition of these natural conditions of the course, a parceling of the course is thought in which the contribution of the course for future graphic designers is identified. In other words, from the first class, the students who enroll in this course are able to learn more about what contributions learning geometry brings to their professional life, for which purpose it is proposed as a course learning objective, namely, to develop skills basic visuospatial thinking, in geometric constructions to support the designs of your portfolio.

Topics such as visuospatial skills, visualization, and spatial ability have been developed since 1928 when analyzing perception and retention of geometric shapes and ease of manipulating mental images [1]. However, these analyzes were carried out from the perspective of psychology in their attempt to characterize abilities inherent in the human being, relate them to talents [2-4] and abilities formed over time. In mathematics education, visualization has taken hold since the spatial ability characterization works in 1973 [5]. The representation of signs, symbols, and diagrams is inherent in mathematics to represent abstract notions, there is a spatial aspect involved, that is, visualization is implicated in its representation [6]. Consequently, one of the questions that come from the line of research characterized in mathematics education as visualization and learning in mathematics education, proposes to inquire about what aspects of classroom cultures promote the active use of effective visual thinking in mathematics? To this end, this article proposes address aspects of representation and dimensionality from the description of some selected tasks of the group participants, who contrast the first representations with their final activities. Starting from the characterization of spatial skills, and its implications in a geometry course for first semester students, it is proposed to analyze two experiences focused on the concepts of representation and dimension based on the results obtained by a group of students.

2. Spatial abilities

Different authors have defined spatial skills with approaches from mathematical education and cognitive psychology. Likewise, spatial ability is considered as the capacity to generate, retain, recover and transform well-structured visual images. In this way, it is possible to measure different aspects of spatial ability by making tests that highlight the different aspects of this process [7].

From this definition, ten types of spatial abilities are characterized, namely (1) visualization (Vz) or general visualization (Gv), which corresponds to the ability to perceive spatial patterns accurately and to compare them with each other; (2) Spatial orientation (OE), refers to the ability not to be confused with the different orientations in which a spatial pattern can be shown; (3) closure flexibility (Cf), refers to exercises that contain hidden figures and patterns and copies, in these exercises the main task was to find a spatial form in a visual field despite distractions; (4) spatial relations (SR), refers to the factors that had loads, especially only the relatively simple accelerated tests that include cards, figures and flags are considered; (5) Spatial exploration (Ss), this point refers to a factor characterized as the speed in the visual exploration of a complicated or wide spatial field; (6) perception speed (Ps), this speed refers to the pairing speed of visual stimuli), visual memory (short-term memory for visual stimuli); (7) serial integration (SI), is similar to successive perception; (8) closure speed (Cs), identified as the speed of pairing of incomplete visual stimuli with their long-term memory representations; (9) visual memory (Vm), memory factor for images and the relationships of their attributes; and (10) kinesthetic (K), corresponds to speed of making left-right discriminations. Based on these factors, many tests that characterize spatial abilities were created using different forms of application, the use of projected cards being the most used for this type of activity. For the purposes of this analysis, the use of the SR, Cf and Cs categories is proposed.

In addition to the complementary visualization processes Interpretation of the figural information (IFI) and visual process (VP) [8].

3. Methodological context: dynamic geometry

This proposal was developed within the framework of the graphic design course, which aims to publicize the design and execution of a geometry course for 27 students based on the implications of the recognition of shapes, representation and dimension in the professional life of graphic designers, this course was designed to be developed with paper representations, and also with dynamic geometry software. For the case of this work, two compositions will be presented developed by freehand by the students; each of the works proposed in the course has specific objectives that allow the development of visualization skills to recognize the properties of classic geometric shapes, with which they finally developed a proposal for a professional portfolio, which involved concepts, representation and characterization of the dimension.

For the case of this analysis, the use of representations of three-dimensional objects is proposed. The first, related to a single piece placed on a table in the center of the classroom, but not a single position of the people who observed the piece in the center of the room. The second experience corresponds to an image captured in photography, which was previously built with pieces of Lego for students to identify the orthogonal projections (plan, right elevation, front elevation, bottom plan, left elevation and rear elevation). The spatial abilities SR, Cf and Cs are involved in both exercises, which will be analyzed below.

4. Two-dimensional representation of the three-dimensional object

This exercise consists of putting a single piece in the center of the classroom [9] so that the students, from the place where they are, perform the respective representation of the object, maintaining a distance of at least 1 meter from the object, which allows not approaching it, so as not to manipulate the design scene. And the object remains in place until the last student delivers the activity, this in order not to involve Vm's spatial ability, since the objective was to achieve the representations of the object guaranteeing that they could perceive it and portray the parts they had in front. After this, the students are authorized to register this image in a photograph taken by the cell phone to verify that the construction made corresponds to what is in the view in front of them.

Figure 1 shows the object to be represented in two dimensions. When observing the figure, students must perform IFI to extract the general characteristics of the object and record on the sheet the parts of the figure, that is, a set of segments. But, also, the students must recognize the SR, because these lines maintain some characteristics, for example, of perpendicularity and parallelism between the base and the cover. Along with the SR appears the Cf, which allows students to recognize the figure as a whole, and not in conjunction with the table (under it) or the board (at the bottom of the object), that is, it allows to remove external conditions to the object to capture the characteristics. And finally, the built-in spatial ability corresponds to the Cs, which allows us to remember throughout the process, for example, the angle at which the cover is arranged, and allows us to remember it quickly, and keep it in mind until the construction is finished.

As it is observed in the representations made by the students, in Figures 2 to Figure 6, not everyone enters the university with technical drawing knowledge (for students of middle basic education), which allows them to quickly develop other skills typical of designers graphics, as well as they are not used to using measuring elements for constructions as a ruler or protractor. In Figure 2 and Figure 3, the students present their Cf skills through the representations, since they preserve proportionality and characteristics of the white base proposed in Figure 1, however, they do not demonstrate a correct IFI, indicating a contrary direction of the cover red representation, like the representations made by students 3, 4, and 5. Despite this, students 1 and 2 show evidence of having correctly applied the SR by maintaining the characteristics of three-dimensional representation, preserving the proportions between the base and the cover.

Figure 1. Real object for two-dimensional representation.

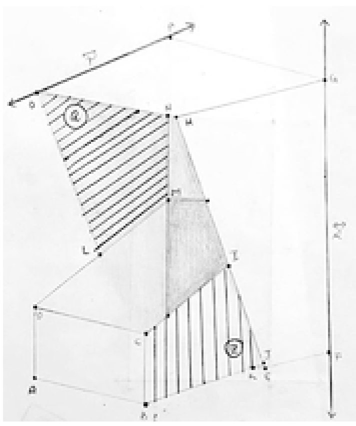


Figure 2. 2D-representation of the three-dimensional object by student 1.

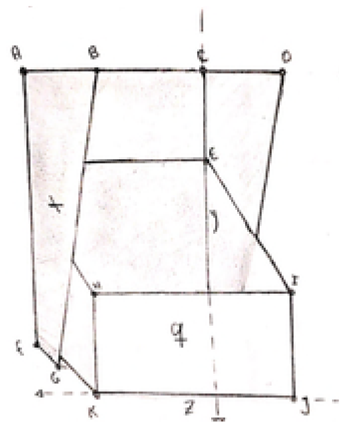


Figure 3. 2D-representation of the three-dimensional object by student 2.

Otherwise, it happens with students 3, 4, and 5 when trying to record the red cover, student 4 does not recognize SR in the construction of the parallel segments, namely $\overline{ie}$ with $\overline{jf}$, and the construction of the parallels between $\overline{hk}$ with $\overline{jf}$, in addition to the lack of depth of the base represented by the ABDC quadrilateral (Figure 5). In the case of student 5, the elaboration of the cover is proportionate but does not save the SR with respect to Figure 1, however, the base of the figure lacks depth. In addition, the lack of understanding between the characteristics of the parts of the figure is evident, indicating only one end of the segment (G), as the vertex of the quadrilateral, which is supposed to represent the base (Figure 6). Finally, student 3, does not present evidence of IFI, when interpreting a disproportion between the measurements that make up the base and the cover of Figure 1, because it indicates a single body demarcated by the 8-sided polygon, however, the SR it is not represented in this construction (Figure 4). These constructions allow forming representations of physical models in students, even of basic levels of school education, as for example, representations of force diagrams, where the forces depend on the constructions based on the properties of the triangles.

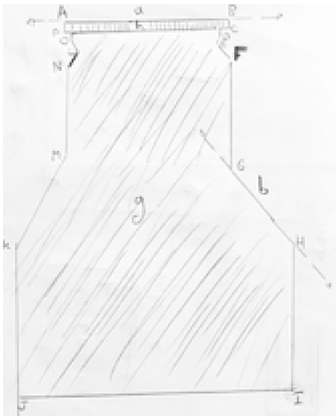


Figure 4. 2D-representation of the three-dimensional object by student 3

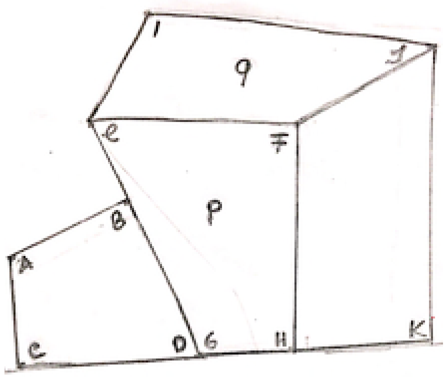


Figure 5. 2D-representation of the three-dimensional object by student 4.

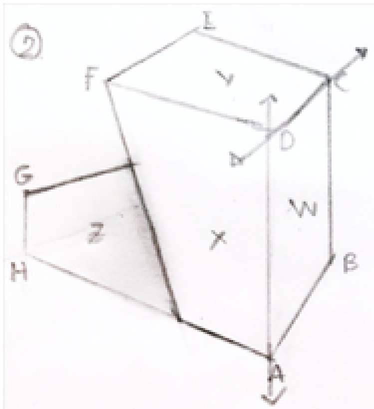


Figure 6. 2D-representation of the three-dimensional object by student 5.

5. Two-dimensional representation and object planning

The second experience consists of presenting the students with a real object with faces defined by perpendicular planes like the one presented in Figure 7, built with a Lego base. The representations around the main one is only shown here for the analysis of experience.

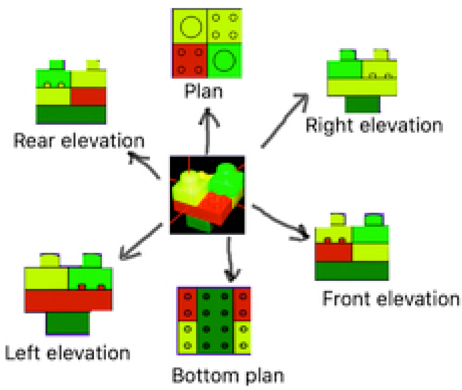


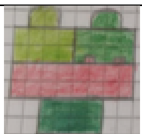
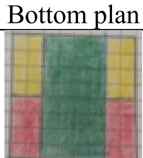
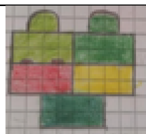
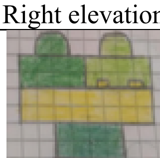
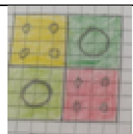
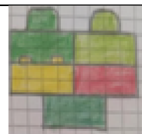
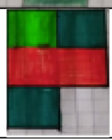
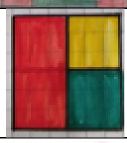
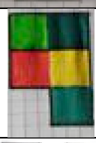
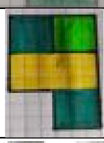
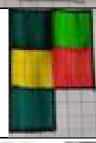
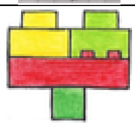
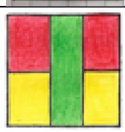
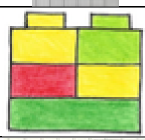
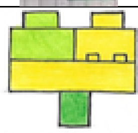
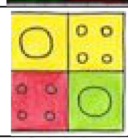
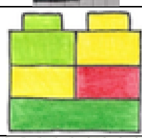
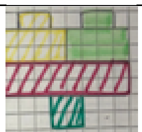
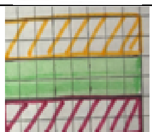
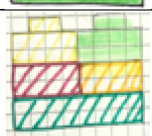
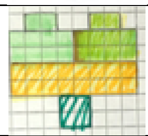
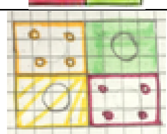
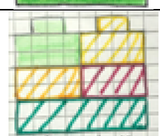
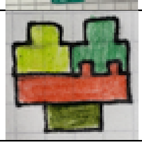
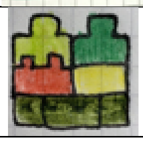
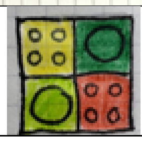
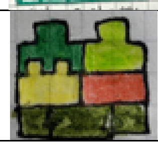
Figure 7. Orthogonal projection from real object.

For this type of activities, it is necessary to avoid the use of common forms, because this leads to the understanding of prototypes [10]. So, for the construction of the orthogonal projection views, figures were proposed that wrapped different colors so that, when doing the IFI, the students recognized one more attribute: color, apart from the shape and arrangement of the pieces. The activity consisted of making the projections: Plan, Right elevation, front elevation, bottom plan, left elevation and rear elevation, of a single figure for the whole group. The figure was projected on a photo that represented a single point of view, in order to avoid saying: "I saw it in another position and therefore it was different for me." However, the visualization of the real piece was allowed, without the opportunity to manipulate it, since the objective was to achieve representation from the establishment of SR.

In this exercise, it is clear that Cf skills must be reflected, since only 3 views of the object are seen, the rest is achieved by relationships between the pieces arranged there. The exercise was started in class and subsequently delivered, so the students had to give samples of Cs because they did not have the original piece, but the photo of Figure 7 to achieve the construction of the indicated projections.

Table 1 shows the representations made by the students on their sheets. The use of the grid sheet was not a limitation, although this strategy would lead to a correct SR since, without the lines of the grids, the students had to make a correct interpretation of the relationships between the pieces in the absence of a guideline for their construction. When analyzing the representations of the five students, listed in the first column of the Table 1, it is evident that student 2 does not understand a correct IFI, since the dark green piece is in the middle of the red in the left elevation representation. Likewise, the student maintains a constant understanding of the location of the piece in relation to the others. From the above, we can deduce that he has not developed signs of SR in this activity. Student 1 performs a correct abstraction of the representations left and right elevation but does not do it with the other four projections, because, despite the fact that the colors and the relationship between them are adequate, the pieces when taking the indicated view are represented with a slight 90-degree rotation counterclockwise in all representations. Next to the correct answers, student 5 performs an adequate interpretation of all the projections except the elevation plan, since the disposition of the pieces is not in adequate SR, nor does it maintain the proposed colors, and does not correspond to any of the rotations of the piece. Student 4 adequately performs the representations: left elevation, front elevation, right elevation and rear elevation, which implies that for these constructions the student made a correct IFI, but there was no adequate SR between the elements of plan and bottom plan because it rotated the projections 90 degrees counterclockwise. Finally, student 3 is the only one who adequately performs the representations of the proposed three-dimensional figure, therefore, in this activity, he achieves SR, Cs, Cf, and IFI.

Table 1. Representations from five students under orthogonal projection from real object.

#	Left elevation	Bottom plan	Front elevation	Right elevation	Plan	Rear elevation
1						
2						
3						
4						
5						

According to the evidence in the activity, students must face more experiences of this type [11-13]. By making correct interpretations of the observed three-dimensional shapes, research reports the need for manipulation of virtual objects to develop SR skills in students [14-16]. Also, these results show that these activities can be proposed to develop an early representational geometry, allowing in higher grades, in school physics, a correct interpretation of the shape and involving movement variables, these representations allow approaching relevant solutions to the problems raised.

6. Conclusions

It is worth noting that the development of these skills is done from the different strategies proposed in secondary and/or middle basic education, so it would be expected that students enter university centers with basic skills for handling measuring instruments, representation structure, in addition to basic geometry concepts. However, when we find the representations projected in this article, it is possible to identify the lack of articulation of mathematical knowledge between the different educational levels. Therefore, the level of knowledge with which they enter, in a certain way, is due to the lack of rich experiences in representations and development of creativity from common elements. In addition to this, it is necessary that future generations of mathematics teachers, who dedicate themselves to teaching geometry at basic and intermediate levels of education, must necessarily understand that university mathematics is different from school mathematics and that, furthermore, experiences that are not experienced during their professional training should be sought and recreated in schools. If a teacher learns in an environment of experimentation of different experiences, surely, they will have an adequate repertoire of experiences to adapt and offer according to the conditions of the courses they take. Otherwise, the method with which the teaching of geometry is assumed will perpetuate the recording of erroneous representations for lack of skill development.

Regarding offering rich training experiences in representations, for graphic design students, it allowed us to account for the contributions that would be made to the development of SR, Cs and Cf skills. According to the experience of the 5 students selected for this cut of the research allows us to recognize that adequate strategies can improve students' abilities and that they possibly use these strategies in the conception of shapes, dimension and representation when developing their portfolio proposals as future graphic designers. However, these results do not apply only to university students, but can be proposed as teaching sequences from school education and, with these, you can approach adequate representations of school physics teaching, by being able to manipulate representations and move between their properties.

References

[1] Guttman A, Epstein E, Amir M, Guttman L 1990 Structural theory of spatial abilities *Applied Psychological Measurement* **14 (3)** 19

[2] Lohman D 1994 Spatially gifted, verbally inconvenienced *Proceedings from the 1993 Henry B and Jocelyn Wallace National Research Symposium on Talent Development* ed Colangelo N, Assouline S G, Ambroson DA L (Dayton: Ohio Psychology Press)

[3] Benedicto C, Acosta C, Gutiérrez A, Hoyos E, Jaime A 2015 Improvement of gifted students' visualization abilities in a 3D computer environment *Proc. of the 12th International Conference on Technology in Mathematics Teaching* (Portugal: University of Algarve)

[4] Poltrock S, Brown P 1984 Individual differences in visual spatial ability *J. Intelligence* **(8)** 45

[5] Bishop A J 1973 The use of structural apparatus and spatial ability – a possible relationship *Research in Education* **(9)** 7

[6] Presmeg N 2020 Visualization and learning in mathematics education *Encyclopedia of Mathematics Education* ed Lerman S (Cham: Springer)

[7] Lohman D, Pellegrino J W, Alderton D L and Regian J W 1987 Dimensions and components of individual differences in spatial abilities ed Irvine SH and Newstead SN *Intelligence and cognition*: Contemporary frames of reference (Netherlands: Dordrecht) pp 59

[8] Lohman D F, Pellegrino J W, Alderton D L, Regian J W 1987 Dimensions and components of individual differences in spatial abilities *Intelligence and Cognition: Contemporary Frames of Reference* vol 38, ed Irvine S H, Newstead S N (Dordrecht: Springer) pp 253-312

[9] Bishop A 1983 Spatial abilities and mathematics thinking- A review *Adquisition of mathematics concepts and process* ed Lesh R & Landau (New York: Academic Press) chapter 1
[10] Acevedo-Rincon J P 2020 Relevance of the mathematics teacher's specialized knowledge model in the planning and interpretation processes at the spatial thinking *J. Phys. Conf. Ser.* **1514** 012019:1
[11] Acevedo-Rincon J P 2020 Spatial concepts in individualization, subjectivities and singularization processes Spatial concepts in individualization, subjectivities and singularization processes *J. Phys.: Conf. Ser.* **1514** 012028:1
[12] Hill H, Loewenberg D, Schilling S 2008 Unpacking pedagogical content knowledge: Conceptualizing and measuring teachers' topic-specific knowledge of students *Journal for Research in Mathematics Education* **39(4)** 37
[13] Acevedo-Rincón J P, Flórez-Pabón C E 2019 TelEduc: A virtual learning environment for teaching and learning at the University of Campinas, Brazil *J. Phys. Conf. Ser.* **1161** 012023:1
[14] Hershkowitz R, Ben Haim D, Holes C, Lappan G, Mitchelmore M, Vinner S 1990 Psychological aspects of learning geometry *Mathematics and Cognition* ed Nesher P, Kilpatrick J (Cambridge: Cambridge University Press)
[15] Gutiérrez A 1996 The aspect of polyhedra as a factor influencing the students' ability for rotating them *New directions in geometry education* ed Batturo A R (Brisbane: Centre for Math. and Sc. Education, QUT)
[16] Gutiérrez J D, Gallo O F, Mesa Jaramillo C M, Monsalve O, Múnera J J, Obando G J, Posada F A, Silva G, Vanegas M D 2006 *Pensamiento Espacial y Sistemas Geométricos (Módulo 4)* (Medellín: Editorial Artes y Letras Ltda)