SNOWFLAKE IN THE CONTEXT OF STEAM EDUCATION OR OVERCOMING A MISCONCEPTION

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СНЕЖИНКАТА В КОНТЕКСТА НА STEAM ОБРАЗОВАНИЕТО ИЛИ ЗА ПРЕОДОЛЯВАНЕТО НА ЕДНА МИСКОНЦЕПЦИЯ

Abstract

Key ideas about STEAM education are fleshed out on snowflake research. The focus is on the geometric shapes of snowflakes and several technologies for creating snowflake patterns. Computer environments, cutting plotter, augmented reality, 3D printer, drone, etc. were used for this purpose. Computer models that can be used to generate images of snowflakes are presented. Both basic steps to create some of the files and ways to use them to get pictures and animations are described. Typical mistakes in creating design patterns of snowflakes are presented. To overcome misconceptions, an opportunity to explore pictures of snowflakes with virtual dynamic constructions is proposed.

Keywords: *STEAM; Computer Models; Augmented Reality; Digital Competence; Misconceptions; IBL; Critical Thinking.*

INTRODUCTION

When conducting events with teachers and leaders in the field of education in order to motivate them to provide conditions for the application of the research approach, one of our tasks has been to organize an experience of elements of the research process, so that they can consciously support at different levels its implementation in education. A snowflake scenario was developed by the MASCIL project and distributed on the SCIENTIX portal [1]. The topic "Snowflake" turned out to be very suitable both in working with teachers and students, due to the presence of misconceptions, inclusion of knowledge from different subject areas, opportunities for creative activity, including in the field of art. Some of the teachers later shared that after the experience in the relevant qualification course or conference, they began to look more critically and deeply at the information in the media. The confirmation of the results of the first observations and the observation of the effectiveness in terms of developing critical thinking was the reason to expand the activity on this topic and include elements of it in various trainings - in the context of teamwork, technologies for STEAM education, augmented reality in education, 3D printing in education, artificial intelligence in education, etc. Considering that the creation of snowflake patterns is closely related to traditional holidays, we think it is appropriate to take a permanent place in the context of STEAM education.

For STEM and STEAM

There is no unity in the understanding of STEM (Science, Technology, Engineering and Mathematics) and STEAM (Science, Technology, Engineering, Art and Mathematics) education both in the scientific literature and by the heads of educational institutions. STEM is considered both as a discipline, as a method of teaching and learning, and as a major/career, etc. When considering STEM as an academic discipline, in some definitions only a subject integrating all four disciplines is understood, and in other cases all other possibilities of connecting three or two of the disciplines are considered, including the separation of the four disciplines as independent [2], [3], [4], [5]. We accept the understanding that each of the possible: independent, connected in pairs, in threes or all four educational fields Science, Technology, Engineering and Mathematics enters into STEM education [6]. Similarly, when ART is included in Science, Technology, Engineering and Mathematics, any of the possible singles, pairs, threes, fours, or all five educational areas are parts of a STEAM education. We will also use the entries entered $STEAM^{(1)}, STEAM^{(2)}, STEAM^{(3)}, STEAM^{(4)}, STEAM^{(5)}$ to denote the number of educational fields that are included in a particular STEAM study (similar to $STEM^{(1)}, STEM^{(2)}, STEM^{(3)}, STEM^{(4)}$), as well as Venn diagram visualization (Fig. 1), using five-fold rotational symmetry of a curve [6].

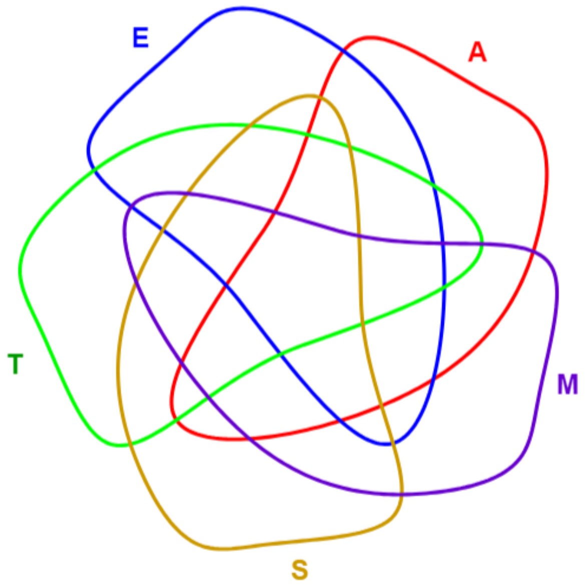

Fig. 1. STEAM preview

Although the focus is on the geometric shape of snowflakes, technology and design, knowledge of chemistry and robotic systems is also applied, so the topic can be included in the $STEAM^{(5)}$ area and accordingly - in the central part of the Venn diagram visualization (Fig. 2).

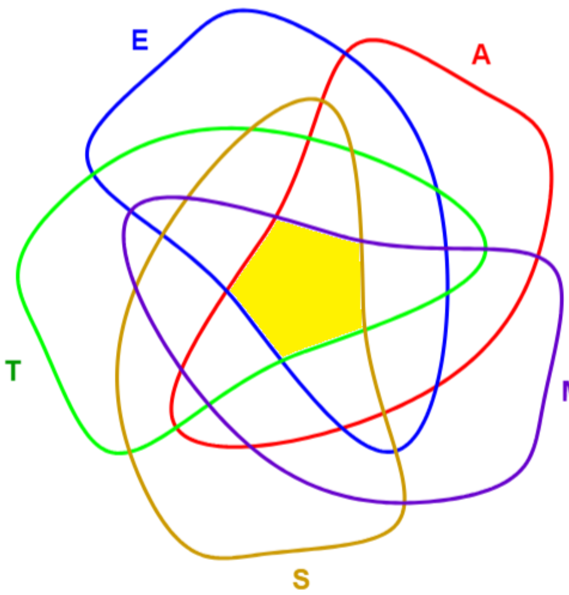

Fig. 2. $\boldsymbol{STEAM^{(5)}}$

Snowflake Misconceptions

A snowflake is a real object, it has a crystalline structure. Its characteristic is the presence of six axes of symmetry, which is due to the hexagonal crystal lattice.

There are two typical mistakes when creating snowflake patterns - using rotational symmetry other than six-fold, and using six "branches" but with rotation at different angles. Fig. 3 presents the results of 79 teachers when sketching two snowflakes, in terms of the number of uses of six-fold rotational symmetry between them.

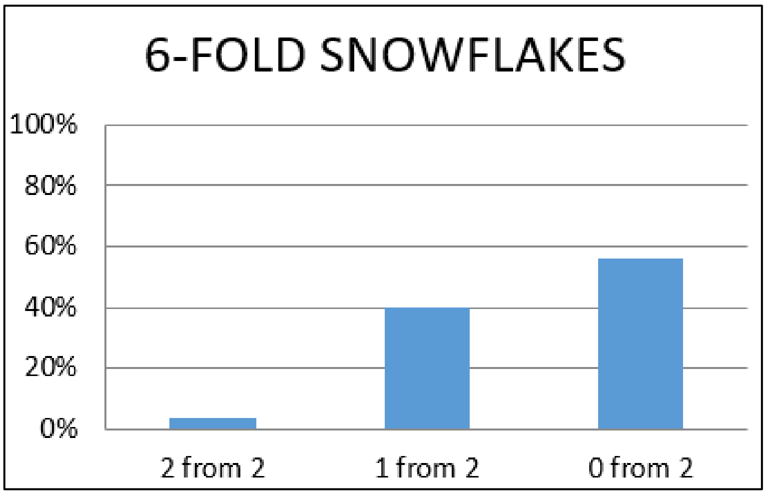

Fig. 3. Number of uses of six-fold rotational symmetry when sketching two snowflakes

In fact, 96% of those tested used at least one non-6-fold rotational symmetry to depict the snowflake. Images with 8-fold symmetry predominate, followed by 4-fold and 5-fold symmetry (Fig. 4).

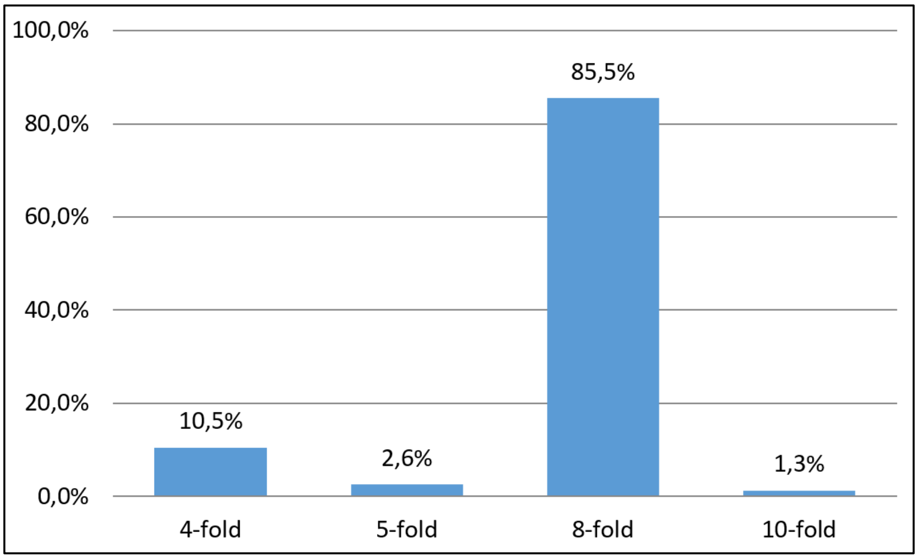

Fig. 4. Distribution of results that do not have rotational symmetry

It is also interesting to compare the two snowflakes from each pair. The aspiration of the tested was that they were different, and the comments during the one-minute sketching were usually related to debating the existence of two identical snowflakes (Fig. 5).

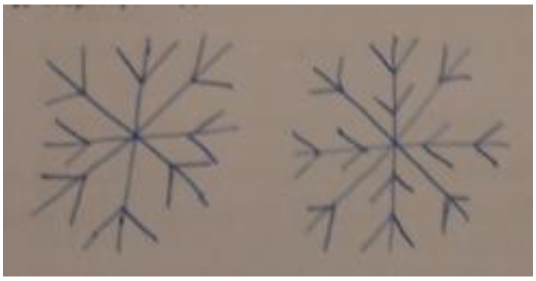

Fig. 5. Sketched models

These results have been confirmed over the years, as well as the reaction of people who have already "passed this lesson". The specified errors are observed in many of the snowflake models used in the media, in Christmas and New Year decorations in public spaces, on book covers dedicated to the snowflake and others.

MATHEMATICAL BASIS

The essential characteristics of a snowflake from a geometric point of view are sixfold rotational symmetry, the presence of six axes of symmetry, a center of symmetry. It is appropriate to use photographs of snowflakes and examine them to independently rediscover the number of rays and the number of axes of symmetry of snowflakes. When creating the files, photos of Wilson Bentley and Alexey Kljatov [7], [8], (Fig. 6) were used.

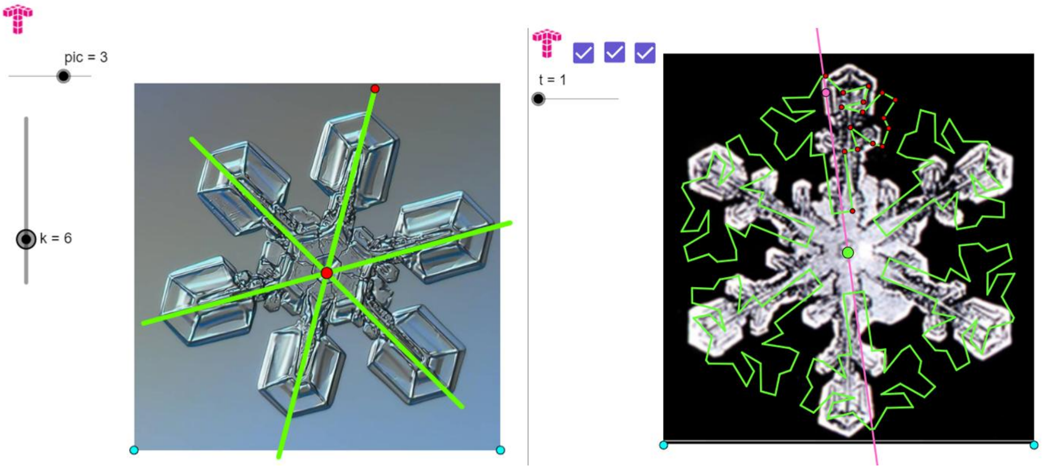

***Fig. 6. Examining snowflakes for geometric properties*[1]**

SNOWFLAKE PATTERNS

Here we will present computer models of snowflakes that represent dynamic constructions. Thus, when changing any of the elements of the dynamic construction, the shape of the figure changes, but the condition for the presence of six-fold rotational symmetry and an axis of symmetry is preserved (hence the presence of six axes of symmetry and a center of symmetry). The computer models are made with dynamic software GeoGebra [9] and are provided with free access at the indicated addresses.

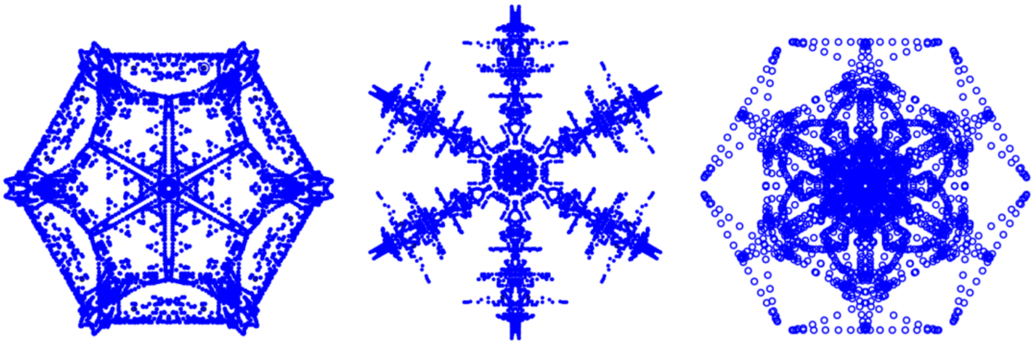

***Fig. 7. Patterns of freehand drawing with the point tool*[2]**

It's convenient to create snowflake drawing tools with objects that leave a trail as they move. For this purpose, together with the object, its image with axial symmetry is constructed, as well as their images with six-fold rotational symmetry. For example, we construct point A, its symmetric one with axial symmetry (for the axis of axial symmetry here we use the ordinate axis), their images at the same rotation with an angle of 60^0 (for the center here we use the origin of the coordinate system). We set the points in trace mode and when moving the point A compositions are obtained as in Fig. 7. Additional effects are obtained by changing the shape of the point.

[1] Toni Chehlarova “VirMathLab” Available at: https://cabinet.bg/content/bg/html/d22052.html and https://cabinet.bg/content/bg/html/d22053.html (last view: 02-08-2024)
[2] Toni Chehlarova “VirMathLab” Available at: https://cabinet.bg/index.php?contenttype=viewarticle&id=511 (last view: 02-08-2024)

Polygons, curves, solids, etc. can be used as a drawing tool instead of a point. The images of snowflakes in Fig. 8 are derived from computer models in which the drawing tool is a triangle.

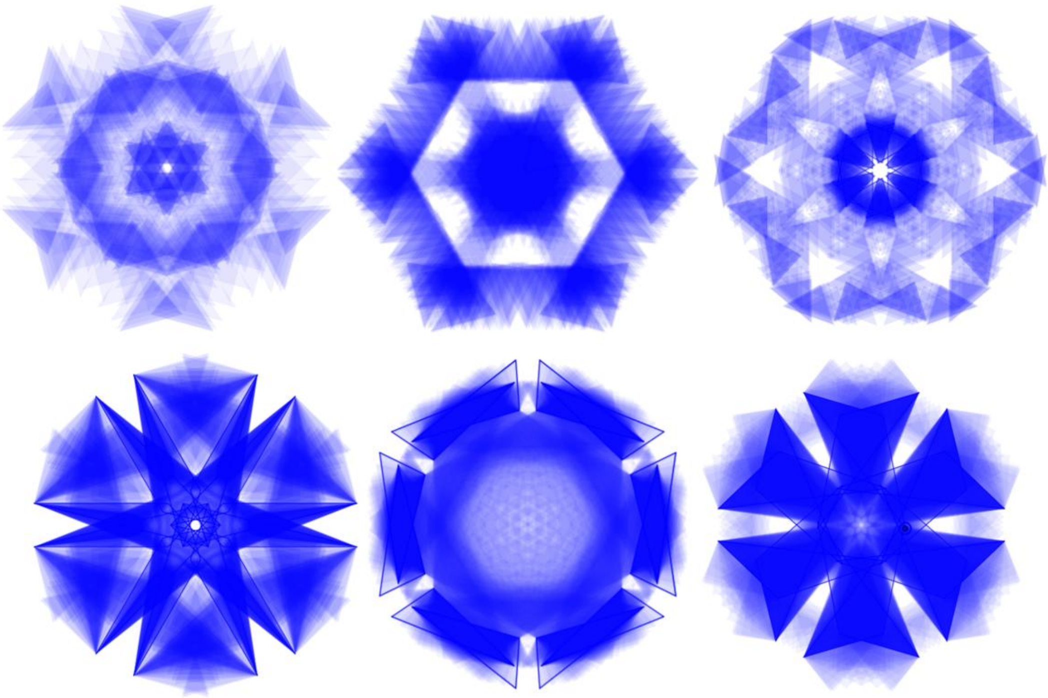

Fig. 8. Patterns of freehand drawing with the triangle tool[3]

In some of the computer models, only the entire triangle can be moved, in others - both its sides and vertices. Variety is also achieved by changing the transparency of the triangles.

Fig. 9 presents several results from files where rotationally symmetric curves are in "trace" mode.

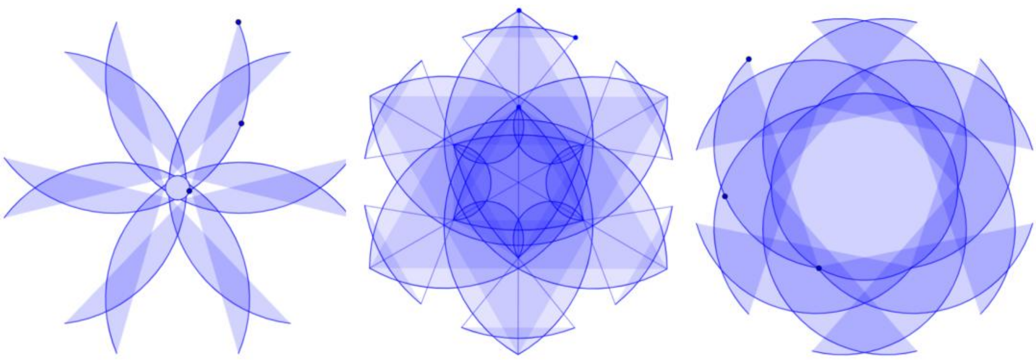

Fig. 9. Freehand drawing patterns with the curve tool[4]

A snowflake image can also be obtained using different styles of sections (Fig. 10). On construction, one end of the first section constructed is the center of the rotations.

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[3] Toni Chehlarova "VirMathLab" Available at: https://cabinet.bg/index.php?contenttype=viewarticle&id=512 (last view: 02-08-2024)

[4] Toni Chehlarova "VirMathLab" Available at: https://cabinet.bg/index.php?contenttype=viewarticle&id=516 (last view: 02-08-2024)

Fig. 10. Using section styles[5]

The lines used to create the last file at this address are:
O= Intersect(xAxis, yAxis)
A= (0, 4)
F= Segment(A, O)
L1=Sequence(Rotate(A, k (360°) / 6, O), k, 1, 6)
L2=Sequence(Segment(Rotate(A, k (360°) / 6, O), Rotate(O, k (360°) / 6, O)), k, 1, 6)

The following is a presentation of a dynamic file for generating snowflakes, in which there are both moving points and sliders-parameters for changing the shape (Fig. 11). Another feature is that after using lists and row commands, the final figure is a single polygon:
L1={A1, A2, A3, A4, A5, A6}
L2=Sequence(Reflect(Element(L1, 7 - k), yAxis), k, 1, 6)
L3=Join({L1, L2})
L4=Join(Sequence(Sequence(Rotate(Element(L3, k), p * 60°, O), k, 1, 11), p, 1, 6))

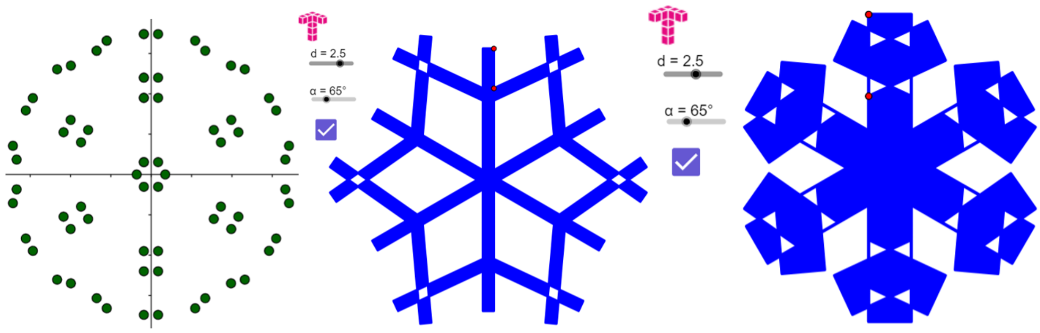

Fig. 11. Using lists[6]

There are various snowflake-shaped fractals, the most famous of which is the Koch Snowflake fractal. It is suitable to be studied by different age groups with different level of complexity. We recommend using videos or viewing dynamic models of the Koch Snowflake to demonstrate both self-similarity and the fact that its face is finite and its perimeter infinite. To provide aids for visually impaired people, we recommend 3D printing of such models (Fig. 12).

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[5] Toni Chehlarova "VirMathLab" Available at: https://cabinet.bg/index.php?contenttype=viewarticle&id=513 (last view: 02-08-2024)
[6] Toni Chehlarova "VirMathLab" Available at: https://cabinet.bg/index.php?contenttype=viewarticle&id=515 (last view: 02-08-2024)

Fig. 12. Koch's Snowflake: iterations, 3D printed models, video material[7]

The models using the so-called turtle geometry is appropriate to be associated with a construction algorithm as a mathematical sketch. For example, a suitable task is to compare the algorithm of building on snow captured by a drone with the algorithms of staying with turtle geometry (Fig. 13).

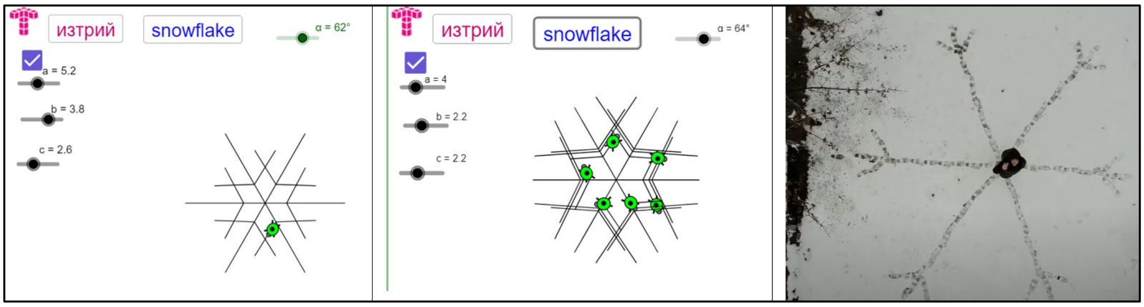

Fig. 13. Comparing algorithms[8]

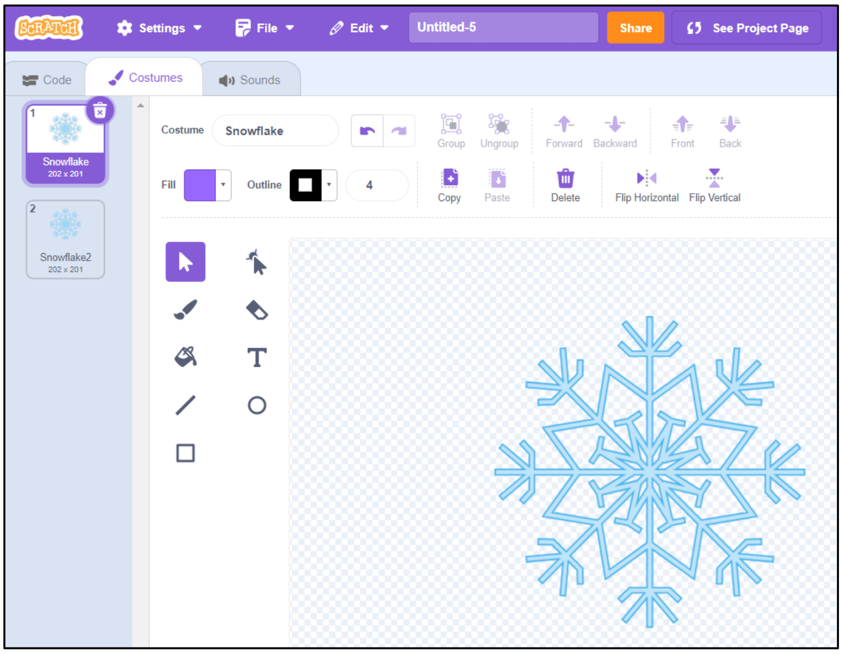

Fig. 14. Snowflake Misconception in Scratch

[7] Toni Chehlarova "VirMathLab" Available at: https://cabinet.bg/index.php?contenttype=viewarticle&id=144 and https://cabinet.bg/index.php?contenttype=viewarticle&id=145 and https://cabinet.bg/video/Fractal_Koch_video5.mp4 (last view: 02-08-2024)

[8] Toni Chehlarova "VirMathLab" Available at: https://cabinet.bg/index.php?contenttype=viewarticle&id=518 and https://www.youtube.com/watch?v=-7nE_ytPu5A (last view: 02-08-2024)

This idea can also be used when working with Scratch. We recommend when working with Scratch to build your own model of a snowflake, and not to use the proposed model in "suits" (Fig. 14).

In TechnoMagicLand, in the "Experimentarium" building of Sofia Tech Park, one of the demonstration installations is dedicated to research with the snowflake and, in addition to working with several of the already described virtual models, it also includes research with mirrors, with which emphasis is placed on mathematical properties (Fig . 15).

Fig. 15. In TechnoMagicLand

Augmented reality, virtual reality and artificial intelligence are the next challenges in creating snowflake patterns (Fig. 16).

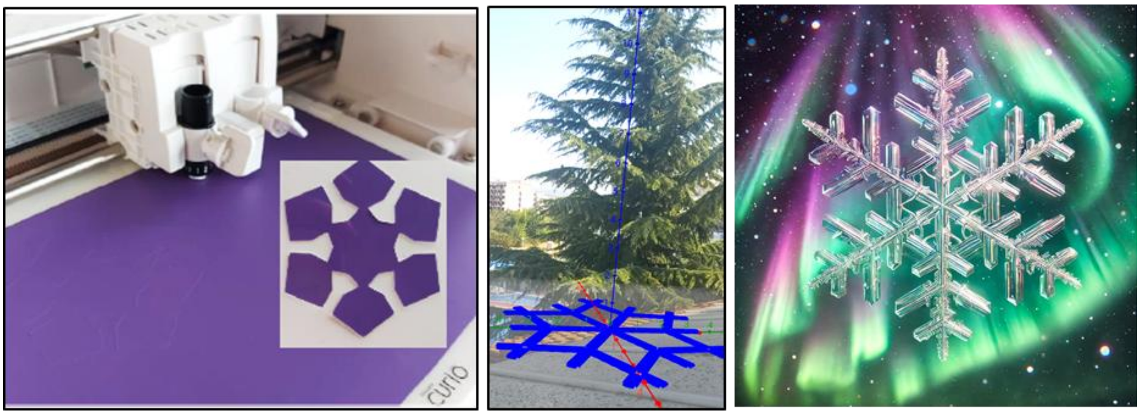

Fig. 16. Snowflake with cutting plotter, augmented reality, artificial intelligence

The first "works" of ChatGPT were of ten-fold and eight-fold symmetry, which confirms the need to clear the Internet of wrong information. Using paper cutting, 3D pen, embroidery, knitting, stringing beads, pixel art mosaic - with "thermal beads", clay, cake dough, plotter cutter, engraver, robot are some ideas you can find in [10], [11], [12]. Fig. 17 shows Snowflake with fusing technique, material glass.

Fig. 17. Snowflake with fusing technique, material glass

More educational resources related to computer models for rotational symmetry and the snowflake (for example, with animations that relate to both 'falling snowflakes and changing shape') can be found in the Virtual Mathematics Laboratoty in the Institute of mathematics and informatics of the Bulgarian Academy of Sciences [13], [14].

DISCUSSION

Interesting project activities can be related to snowflake research, for example Kepler's treatise "On Hexagonal Snowflakes" [15], with snowflake classifications by Israel Perkins Warren, René Descartes, Ukichiro Nakaya, with modern snowflake classifications.

In Bulgaria, work is being done on building a complete educational STEM environment in schools, which is related to renovation, modernization and creation of a new space and environment for project and entrepreneurial competence and teamwork outside the classic classroom system [16]. A large number of STEM centers have the equipment to implement some of the models proposed here.

Students should use available resources not only in specialized STEM classes, but also in other curricular or extracurricular forms.

CONCLUSION

The purposeful activity of overcoming misconceptions about the snowflake, combined with the application of various technologies and the creation of a final product, contributes to the development of critical thinking, to the formation of competence in the application of various technologies and their selection, to conducting research in various fields and finding solutions to problems, to apply knowledge from different subject areas when performing creative activity.

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