The Experience Workshop MathArt Movement: Experience-centered Education of Mathematics through Arts, Sciences and Playful Activities

Kristóf Fenyvesi
Department of Arts and Culture Studies, University of Jyväskylä, Finland
Ars GEometrica Gallery, Hungary (www.arsgeo.hu/en/)
Experience Workshop MathArt Movement (www.experienceworkshop.hu)
E-mail: fenyvesi.kristof@gmail.com

Abstract

The Experience Workshop Math-Art Movement, a movement advocating experience-centered mathematics education, was established in Hungary in 2008. Almost one hundred scholars, artists, engineers, architects, teachers, craftsmen and toymakers that participate in this movement, developed various forms of interactive and play-oriented combinations of mathematics and arts. By researching the connections between scientific and artistic education, the Experience Workshop Math-Art Movement's members are contributing to the dissemination of new educational approaches. The Experience Workshop Math-Art Movement organizes math-art festivals, art and science workshops, interactive math-art exhibitions, and conferences. It also contributes to the development of new school curricula. Nearly ten thousand students and several hundred teachers and parents have attended the events organized by the movement since its inception. The movement's publications are becoming popular among a growing circle of experts within the Hungarian art and science education community. This article introduces The Experience Workshop Math-Art Movement's main educational activities, including the launching of math-art festivals across Hungary, and the opening of the Ars GEometrica Art – Science – Education Gallery in the Eszterházy Károly College in Eger city. This gallery functions as an experimental venue for the development of new approaches in Hungarian mathematics teacher education.

Overview

The knowledge gained through blurring the boundaries of art, science, and technology becomes our common experience of heterogeneity, and this common experience is also expressed in the transformation of our sociocultural practices. We discover and create new complexities that can reinforce the role and significance of mathematics in society [1]. An integrated approach to art, science, technology, mathematics, and the flexibility of the learning environment that considers all these sociocultural changes can be productively and most efficiently established in the educational system. This should take place concurrently with acquiring new models of networked researching [2], learning through action and reflection, collective cooperation [3, 4], and experiential methods, which often infuse direct experience with the learning environment and content.

The school that is built upon the dogmatic segmentation of knowledge and the pedagogy of strictly fixed roles is less effective today. By now, multi-modal flexibility that involves several variables of the teaching / learning process has simultaneously become an indispensable precondition for meeting the ever-increasing and wide-ranging demands that education has to face today. In the field of experience-centered mathematics education, all these developments prompt us to enlarge the set of pedagogical tools and materials to complement the STEM (Science, Technology, Engineering and Mathematics) integration with aesthetic, creative, holistic design aspects and make the most of the successful models of cooperation among mathematics, sciences, and arts [5].

What do mathematicians mean by 'beauty' and 'creativity'? And for artists who make use of mathematical knowledge in their work, what constitutes a research practice? What happens to mathematical knowledge, discoveries, visualizations, models, and simulations when they become the subject of aesthetic reception, or artistic application, or performance? What mathematical significance can be attributed to a work of art or a game? What new results can be produced from the special perspective that combines mathematics, arts, and games? How can we make the most of these results in education?

In the open network of the Experience Workshop Math-Art Movement for the experience-centered education of mathematics, established in 2008 in Hungary and led by the author of this article, almost one hundred scholars, artists, engineers, architects, teachers of various subjects, craftsmen, and toymakers look for answers to these questions through various forms of interactive, hands-on, skill based, play-oriented, and experiential combinations of mathematics and arts. Our aim is to involve the students and their teachers and families into a vibrant dialogue between the mathematical and artistic points of view and raise our own personal interests in the field where mathematical and artistic thinking and practice merge. By researching the various possible connections between scientific and artistic education the Experience Workshop Movement's members are contributing to the development of new educational approaches that can be fruitfully implemented through the organization of math-art festivals, art and science workshops, interactive math-art exhibitions, conferences, and even in the development of new inside / outside curricula in everyday teaching [6].

The Experience Workshop contributes to several international projects. It was an official event of the European Year of Intercultural Dialogue in 2008, and of the European Year of Creativity and Innovation in 2009, and of the Pécs2010 - European Capital of Culture project in 2010. In 2011-2012 the Experience Workshop leads a Hungarian-Croatian cross-border co-operation project for the development of mathematics, science and art education in Hungarian and Croatian high schools. The members of the movement are cooperating with many local and world organizations, institutions, international research groups, university programs, and art communities which are in turn interested in the relationship between mathematics, art, science, games, and education. Nearly ten thousand students and several hundred teachers and parents have attended our events and our publications [7, 8] are becoming popular among a growing circle of experts in the Hungarian educational, artistic, and scientific discourses.

Figure 1: *The Experience Workshop's logo, designed by Bálint Rádóczy, combines a paradoxical geometric object, the Möbius strip, with a difficult mathematical idea, the infinite.*

The goals of the Experience Workshop:

a) Integrating the pedagogical results of using art, science, and play-centered learning into the teaching of mathematics in activity- and experience-centered educational programs.
b) Organizing various math-art events in Hungary and in its neighboring countries for the introduction of best practices concerning the experience-centered teaching of mathematics.
c) Familiarizing the students and the current and future teachers in public education with the most recent results of experience-centered mathematics education; researching, collecting, and publishing the main domestic and international achievements and making these accessible for the broadest scientific, artistic, and teaching communities.
d) Expanding the set of tools used for increasing a learner's mathematical, logical, combinatorial, and spatial abilities, structured thinking skills, developing perception, aesthetic sensibility, motivating

collaborative problem solving, interdisciplinary and inter-artistic approaches on all levels, and in every field of education.

The importance of using tools in experience-centered mathematics education

Representatives of the most notable trends in reform pedagogy (e.g. Montessori, Steiner, Freinet, Petersen, Neill, Parkhurst) and the activity-, experience-, and game-centered alternative pedagogies that draw upon their work all attach great importance to the use of tools embedded in the teaching and learning process [9]. The educational purpose of the revival of traditional crafts, the play-oriented and creative activities involving various objects, the use of modeling kits, manipulatives, and multimedia teaching materials, creating artworks and innovatively re-organizing the learning environment together can create various opportunities. These opportunities should be given a key role in the math-art education practice: *"Mathematics, the language of science, is secured by the young child's understanding of basic symmetries: translation, rotation and reflection. These rudimentary transformations are used to develop a primitive topological space constituted by relations of proximity, separation, surrounding and order. These early mathematical relations are qualitative, not quantitative and their representations are structured symbolically; not as numbers. They are developed through work with 3-dimensional activities such as block play, woodworking and sculpture and expressed through the practice of art: drawing and painting."* [10]

It has been shown that a creatively used educational tool – which can be a simple piece of fruit, a game, a toy, a scientific model or a work of art – can to a considerable extent alter the relationship of students to their studies and even to their teacher and to each other: "*All these activities extend the standard teaching programs and develop the creative thinking of the students by burdening their left and right cerebral hemispheres more or less equally balanced, and by facilitating interaction between the two hemispheres of their brain. The creative artistic practice helps the children to understand and familiarize the algebraically formulated regularities of mathematics, and contributes to their abilities to make abstract mathematics conscious […]. Experience workshops mobilize synergies with a multidisciplinary approach and cooperative learning."* [11]

A tool used in the educational process proves to be well chosen and successful in practice if the activity carried out with it redefines every actor's position in the pedagogical situation. Consider the following conditions: (a) if both the object and the pedagogical method used for its introduction into the process arouse curiosity and stimulate a playful mind, encouraging both the learner and the teacher to engage in discovery, participative analysis, experimentation, creative work or free play, and (b) if both the student and teacher are given the opportunity to change roles occasionally, then the entire structure of the teaching/learning process is flexibly transformed, making the accomplishment of the complex pedagogical objectives much easier.

By using activity-centered teaching methods in mathematics education, the traditional unidirectional communication models can be replaced by cooperative learning methods and content that focuses on the student and is sensitive to the various social and individual challenges. When students participating in the learning process expand their mathematical knowledge and develop their abilities and skills through activities of their own and activities carried out together with their peers, they have more of a need for self-directed learning. At the same time they acquire the complex personal and social abilities that are required for successful cooperation and collective problem solving. The interaction between individual and collective learning through artistic and playful contents pave the way towards a balanced approach enabling the mathematics teacher to act as a facilitator, to bring existing knowledge to the surface in subtle ways, and to create a nurturing atmosphere for learning from one another [12].

As it is often described in the literature on experiential education, these new roles and structures may seem unfamiliar to both students and adults in school: "*Traditionally, students have most often been rewarded for competing rather than cooperating with one another. Teachers are not often called upon for collaborative work either. Teaching has traditionally been an activity carried out in isolation from one's peers, behind closed doors. Principals, accustomed to the traditional hierarchical structure of schools, often do not know how to help their teachers constitute self-managed work teams or how to help teachers coach students to work in cooperative teams."* [13] However, our experiences have shown that the Experience Workshop's events stimulate and make an important contribution to the natural transition from the old school to the experience- and student-centered new structure.

Introducing the experience-centered approach to the teaching of mathematics in Hungarian public education

The connections between mathematics and the arts, the creative and practical application of hands-on activities and, last but not least, the teaching of mathematics using an interdisciplinary and inter-artistic approach have a rich modern tradition and an extensive international system of institutions. Oddly enough and contrary to wide distribution of the originally Hungarian mathematics education tools and mathematical toys (e. g. Dienes blocks, Rubik's Cube), all this is however rather under-represented in Hungarian public education and it is nearly entirely missing from the Hungarian teacher training. The introduction of the results of reform pedagogies and many of their attractive aspects to different public educational institutions in Hungary is often met with numerous difficulties [14]. The development or implementation of a complex pedagogical method in the teaching of mathematics might, in many cases, require the transformation of the entire institutional structure. Given that even a small change affecting teaching norms or the general structure of subjects may give rise to conflicts between the different actors in the education system, most of the pedagogical innovations in the teaching of mathematics can be introduced in public education only in the form of activities carried out outside the regular classes. However, in addition to introducing forms of education outside classes and working out programs designed to identify and develop talents, it is equally important to study and develop the modern methods of education within the school, spread best practices, and recognize and make the most of the simple fact that everybody has a special talent for something.

The state-controlled top-down transformation of the structure of subjects may not be the only way to resolve the conflict between the constraints it imposes on the education process and the interdisciplinary and inter-artistic foundation of mathematical knowledge. Respecting the present structures of Hungarian public education, we explore the interdisciplinary and inter-artistic connections in an experience-centered manner, thereby stimulating the students, their parents and teachers themselves, offering new opportunities for the teaching of specific topics of mathematics. All this requires the math teacher and sometimes the families to engage in research, and have intensive interest in issues of science, art, technology, culture and education that goes well beyond the narrow boundaries of the subject, and the acquisition of a certain level of expertise in the objects, technologies, methods and activities to be used.

Three Examples: The Experience Workshop's GiganTile, The Geometrical Hopscotch and Saxon's Poly Universe Toy Family

Squids-and-Rays. Robert Fathauer's revolutionary *Squids-and-Rays* puzzle, originally with small pieces that resemble sea creatures and fit together in an almost endless number of combinations, is a great set for educational use to carry out open-ended plays that encourages creativity. With the artist's leadership the Experience Workshop's facilitators enlarged the puzzle pieces and after the playful understanding of the

basics of tessellations by tables (Fig. 2), a huge, spectacular 'GianTile Workshop' (Fig. 3) took place at the Hall of the Kaposvár University. In Fathauer's workshop, students explored tessellations using two different shapes of tiles, squids and rays. They learnt what a vertex is and how vertices can be used to characterize a set of tiles. They built the different types of vertices allowed by the *squids-and-rays* tiles. They also learnt the different types of symmetry possible in tessellations and constructed squid-and-ray tilings with each type of symmetry. Large tessellations with five-fold rotational symmetry were also built.

Figure 2-3: *Squids-and-Rays tessellations by Robert Fathauer at Experience Workshop's math-art festival at the Kaposvár University.*

Geometrical Hopscotch. The *Geometrical Hopscotch* is created by a painter Franciska Bali in the framework of the 'Ars GEometrica' course on math-art connections held by Csaba Hegyi DLA and Kristóf Fenyvesi at the Pécs University. The *Geometrical Hopscotch* is a five-piece series of large-scale models of the Platonic bodies. The sides of the three-dimensional bodies can be quickly folded out into the plane and the flat surface can be used as a special kind of hopscotch (Fig. 4-5). It is possible to write, draw or to stick number-, letter-, or picture-cards on the sides to explore all the logical, algorithmic interrelations which stem from the three-dimensional attributes of the bodies and the features of the planar objects. This way the traditional hopscotch game is extendable with a number of individual or cooperative cognitive games which highly support the education processes in the topic of changing between plane and space. The *Geometrical Hopscotch* can just as well be used outdoors.

Figure 4-5: *Ildikó Szabó's Geometrical Hopscotch Workshop for elementary (left) and secondary (right) school students.*

Poly Universe Toy Family. The *Poly Universe Toy Family* (www.poly-universe.com) by the painter János Szász Saxon is a toy for developing geometrical skills (Fig. 6) and an artistic and mathematical form system (Fig. 7) based on scale-shifting symmetry. These colourful geometric shapes are not only designed to aid colour and shape recognition - and to teach the solving of logical puzzles - but also offer the chance to play freely, learning through an artistic game or activity. Progressive use of colour and shape groups, and the encouragement of manual activity and reflective thought, create a constant challenge for the children. This maintains their desire for exploration, producing a continuous feeling of success. Having a direct, tactile connection with the geometric shapes develops children's sense of vision and touch. Through the recognition and discovery of correlations and linkages, cognitive and abstraction skills are improved. Following compositional play with the forms (Fig. 5), incorporating key aspects of geometrical composition and art, children make their own geometric artwork from paper and organise an exhibition in the classroom (Fig. 8). The Poly Universe Toy Family develops key skills in examining geometric shapes, proportions, symmetry, linkage points, directions, and colour combinations. It expands the limits of form and colour composition/combination. It is interesting to place Poly Universe shapes amongst nature (Fig. 7) - eg: as a colourful field of flowers to educate students about the relationship between maths and the natural environment. Such experiences help children develop knowledge, finding creative and imaginative solutions to problems that cross between the abstract and real-world.

Figure 6-7-8-9: *The various uses of the Poly Universe Toy Family by the painter János Szász Saxon and the art critic by Zsuzsa Dárdai.*

The Traveling Exhibition of the Experience Workshop and the Ars GEometrica Art – Science – Education Gallery

The International Traveling Exhibition of the Experience Workshop was established in 2010 and funded by the donations of the participants of Bridges Pécs 2010 World Conference's Grand Exhibition. Our

constantly growing mathematical and artistic collection includes nearly 80 pieces by artists and scholars from all over the world. These artworks are key pieces in the events organized in public schools, universities all around Hungary by the Experience Workshop. They can be used to illustrate the cultural, artistic, architectural and interdisciplinary foundations of mathematical thinking in many different ways.

The promotion and popularization of research activities and the publication of scientific and artistic results for a wider domestic and international audience is essential for the successful management of any higher education institution. Recognizing this need, we began to prepare a course in Science and Art Management in September 2011 at the Eszterházy Károly College of Eger, Hungary, providing a new platform for the training of science and mathematics teachers. Through several examples of internationally recognized initiatives, the course gives students an insight into the professional background of promoting science and art connections as well as giving them an opportunity to test, to try out, and to put into practice the knowledge and skills they have acquired. Practical activities can be conducted in our exhibition space set up at the College, which has been operating as an experimental math-art gallery since September 2011. The workshop gallery, whose unique themes and concept are reflected in its name and in its slogan *Ars GEometrica Gallery: Interactions and Border-Crossings in Art and Science*, functions as a completely new platform in the Hungarian mathematics teacher education. Here the students not only can learn about the best examples of promoting and popularizing science and contemporary art but can also gain professional experience while testing their abilities in special fields of their own interest such as: organizing exhibitions, symposia, and Art&Science Café sessions, the fundamentals of exhibition and education technology, scientific and artistic communication, project management, writing tender applications, learning fund-raising techniques, PR- and media management, web design, presentation techniques, and so on. We organize two to three exhibitions in the Gallery every semester. The opening events of the exhibitions and the Art&Science Café sessions organized during the period of the exhibitions are listed among the highly recognized cultural programs of the city of Eger. Moreover, the scientific symposia related to each exhibition are designed to strengthen the international professional reputation of the Eszterházy College. Together the opening events and the Art&Science Café sessions and the website of the Gallery [16] an excellent platform for popularizing all these contents, the innovativeness of the Eger College together with the famous wine culture of Eger, thereby recognizing the importance of connecting local interests in a global cultural space. The annually organized events of the Gallery will be summarized in the Ars GEometrica Almanac, a publication which will contain artistic and scientific documents produced as a result of the exhibitions, while multimedia material is accessible on the Gallery's website.

Conclusion

As William Byers ingeniously exposed in his book, entitled *How Mathematicians Think,* mathematicians make use of "ambiguity, contradiction, and paradox to create mathematics" [16]. Understanding Byers' insight in a fundamental way can open new perspectives in the mathematics education as well: *"Mathematics educators investigate mathematics as it is learned and taught. Therefore they are forced to consider not only the formal, objective aspects of mathematics but also the human dimension of the subject. They are forced to confront such questions as 'What is meaning?' 'What is understanding?' The result has been that various mathematics educators have developed a rather sophisticated approach to the nature of mathematics. These approaches have in common with my own a desire to free mathematics from an entirely 'objectivist' point of view, 'objectivist' in the sense that the meaning of mathematics is 'out there' in a mind-independent reality."* [16, p. 65] According to the methodical framework of the Experience Workshop, by the study, interpretation and creation of artworks a lot of ambiguous and creative aspects, possibilities of mathematics can be brought to light. Just like many artistic creations can be understood better by studying, interpreting or re-creating the 'mathematical element' in them. As an

addition to the interactive activities offered by the Experience Workshop, the exhibition also shows how artistic-scientific exhibitions and workshops can be connected to schools, universities, festival events, and even art galleries.

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References

[1] M. Niss, *Mathematics in Society,* In: R. Biehler, R. W. Scholz, R. Sträßer, B. Winkelmann eds., Didactics of Mathematics as a Scientific Discipline. Dordrecht: Kluwer Academic Publishers, 1994, pp. 367-378.

[2] F. Vester, *The Art of Interconnected Thinking,* MCB, 2007.

[3] B. Rogoff, *Developing Understanding of the Idea of Community of Learners,* Mind, Culture and Activity, 1994/1(4), pp. 209–29.

[4] B. Rogoff, R. Paradise, R. Mejía Arauz, M. Correa-Chávez, and C. Angelillo, *Firsthand Learning by Intent Participation.* Annual Review of Psychology 2003, 54, pp. 175–203.

[5] S. Kabai, K. Fenyvesi, I. Szabó, E. Stettner, L. Szilassi, L. Vörös, I. Lénárt, Sz. Bérczi (2012): Experience-workshop in mathematics and space education: joyful teaching program in Hungary. 43rd Lunar and Planetary Scienece Conference, #2611, LPI, Houston.

[6] Detailed information on the various activities of the group is accessible on the Experience Workshop's website: <www.experienceworkshop.hu>

[7] S. Jablan, L. Radovic, *The Vasarely Playhouse,* K. Fenyvesi eds, Association for South-Pannon Museums, Hungary, 2011.

[8] K. Fenyvesi and E. Stettner eds. *Hidak: matematikai kapcsolatok a művészetben, a tudományban és az élményközpontú matematika-oktatásban [Bridges: Mathematical Connections in Art, Science and Experience-centered Education of Mathematics.]* University of Kaposvár, 2011.

[9] T. Post, *The Role of Manipulative Materials in the Learning of Mathematical Concepts. In Selected Issues in Mathematics Education,* Berkeley, CA: National Society for the Study of Education and National Council of Teachers of Mathematics, McCutchan Publishing Corporation, 1981, pp. 109-131.

[10] *Why Art? An Exhibition and Examination of International Children's Artwork (Jardin Galerie).* New York: The UBS Art Gallery, 2008, 3.

[11] György Darvas, Kristóf Fenyvesi: *Symmetries In Action! The Hungarian Experience Workshop Movement in the Education of Mathematics and Symmetry Studies through Arts,* 2012. [Manuscript.]

[12] C. Rogers, H. J. Freiberg, *Freedom to Learn*, New York: Merrill, 1993.

[13] Peggy Walker Stevens - Anthony Richards, *Changing Schools through Experiential Education*, 1992: ERIC Digest. ED345929. ERIC Clearinghouse on Rural Education and Small Schools Charleston WV. http://www.ericdigests.org/1992-3/changing.htm

[14] An accurate diagnosis is presented on the challenges for introducing and developing reform pedagogies in Hungary by S. Klein, D. Soponyai eds., *A tanulás szabadsága Magyarországon. Alternatív pedagógiai irányzatok, iskolák, tanárok, tantárgyak. [Freedom to Learn in Hungary. Alternative pedagogies, schools, teachers and subjects.],* Budapest: EDGE 2000 Publishing House, 2011.

[15] <www.arsgeo.hu/en>

[16] William Byers, *How Mathematicians Think: Using Ambiguity, Contradiction, and Paradox to Create Mathematics,* Princeton: Princeton University Press, 2007.