

STEAM Game Design in Higher Education: Poly-Universe Reimagined by the Experience Workshop's Collaboration with the Budapest University of Technology and Economics

Project Report

Kristóf Fenyvesi and Panna Petró

Introduction: Bridging Theory and Practice

The integration of innovative pedagogical methods and tools in higher education has become a focal point for enhancing transdisciplinary learning, particularly in the fields of Science, Technology, Engineering, Arts, and Mathematics (STEAM). A key component of the PUNTE project is the utilization of the educational game Poly-Universe in higher education contexts through the development and dissemination of new educational frameworks. This approach aligns with the growing body of research emphasizing the importance of interdisciplinary learning in STEAM education (Quigley & Herro, 2016; Becker & Park, 2011). The incorporation of game-based learning, such as Poly-Universe, fosters creativity, critical thinking, and problem-solving skills, which are essential competencies in the 21st-century workforce (Gee, 2007; Prensky, 2006). The use of games in educational settings has been shown to increase student engagement and motivation by providing a context where failure is a part of the learning process rather than a definitive outcome (Gee, 2003; Kapp, 2012). Furthermore, the collaboration between educational institutions and game designers, as seen in the PUNTE project, reflects a trend towards a more integrated approach to curriculum development, where real-world applications and industry partnerships enhance the relevance and authenticity of learning experiences. Such initiatives contribute to the broader movement towards a more holistic and interconnected educational paradigm, where the boundaries between disciplines are blurred and learning becomes a dynamic, participatory, and student-centered process (Land et al., 2014; Honey et al., 2014).

The Collaboration: Finnish Experience Workshop and Budapest University of Technology and Economics

In the context of the Budapest University of Technology and Economics, the Finnish Experience Workshop played a pivotal role in facilitating a STEAM-focused course during the academic year 2021–2022. Collaborating with the Department of Mechanical Engineering, the Experience Workshop provided cognitive game inventions, including Poly-Universe, for the Integrated Product Design V. course, offered by the Budapest University of Technology and Economics. This collaboration exemplifies a concerted effort to explore the game design potential of Poly-Universe

and other cognitive games, fostering creativity development and community building within a university context and beyond.

The course's structure, encompassing research, design, and presentation phases, allowed students to engage in a deeply interdisciplinary approach. The Experience Workshop's contribution, particularly through the provision of Poly-Universe, enabled students to reimagine the game in innovative ways, reflecting the broader objectives of enhancing transversal skills and interdisciplinary learning as outlined in the PUNTE project.

This report introduces the details of the course, the methodologies employed, and the innovative outcomes achieved, highlighting the role of the Experience Workshop in bridging the gap between theoretical frameworks and practical applications in the realm of STEAM education.

Insights from Product Design in the Poly-Universe Project for STEAM Education

The Poly-Universe project, with its physical product at the center, the Poly-Universe toolkit, represents an intersection of art, mathematics, and design. A course at the Department of Mechanical Engineering at the Budapest University of Technology and Economics, focusing on Product Design BSc students, provided a unique opportunity to explore and redesign this toolkit. This chapter analyzes the insights gained from this course and their significance for STEAM education.

Re-Imagining the Poly-Universe Toolkit: A Product Design Perspective

1. Understanding the Toolkit's Potential: The course allowed students to delve into the Poly-Universe toolkit's multifaceted design. They explored its two-dimensional and limitless visual building potential, leading to a deeper understanding of how it can be utilized in various educational contexts.

2. Innovation and Creativity: The re-imagining process encouraged students to think creatively and innovatively. They were challenged to find new applications and interpretations of the toolkit, fostering a mindset that aligns with the principles of STEAM education.

3. Interdisciplinary Collaboration: The collaboration between product designers, educators, and artists created a rich interdisciplinary environment. This collaboration mirrored the transdisciplinary nature of STEAM education, where boundaries between subjects are blurred.

Insights for STEAM Education

1. Enhancing Educational Tools: The re-imagining of the Poly-Universe toolkit demonstrated how physical products can be enhanced and adapted to meet the evolving needs of STEAM education. The insights gained from the product design perspective can inform the development of future educational tools.

2. Fostering Creativity in Education: The creative process involved in re-imagining the toolkit offers a model for fostering creativity in education. It emphasizes the importance of experimentation, innovation, and a willingness to explore new possibilities.

3. Connecting Design and Education: The course highlighted the connection between design thinking and educational practice. The principles of design can be integrated into teaching methodologies, encouraging students to approach problems with a design mindset.

4. Real-World Applications: The re-imagining of the Poly-Universe toolkit provided insights into how educational tools can be aligned with real-world applications. The collaboration between product designers and educators ensured that the toolkit's redesign was grounded in practical needs and industry trends.

Implications for the Future of STEAM Education

1. A Model for Interdisciplinary Collaboration: The course serves as a model for interdisciplinary collaboration between product designers, educators, and artists. Such collaboration can lead to innovative educational tools that enhance STEAM education.

2. Integrating Design Thinking into Education: The insights gained from the course emphasize the importance of integrating design thinking into education. This approach fosters creativity, problem-solving, and a willingness to explore new possibilities.

3. Enhancing Physical Products for Education: The re-imagining of the Poly-Universe toolkit illustrates how physical products can be enhanced and adapted for educational purposes. This process can inform the development of future educational tools that align with the principles of STEAM education.

The Spring Semester: A New Focus on Playful Creativity

Körtélyesi Gábor and Panna Petró, along with their guest lecturer Kristof Fenyvesi from the Experience Workshop, started a new project in the spring semester of the academic year 2021–2022, in the Department of Mechanical Engineering at the Budapest University of Technology and Economics. The Integrated Product Design V. course of the Industrial Product Design BSc students' fifth academic semester had a new focus for the traditional Product Redesign challenge. The course consists of a task, a challenge, an industry use case, and a problem space partly defined and offered to the group of 12–17 students for examination, exploration, and experimentation.

This semester was the fifth consecutive block of an entertainment-edutainment-focused experimental product design program. After a cooperative board game redesign course, four courses followed, sharing the same brief: physical, virtual, or meta spaces and the interaction of participatory, collective creativity. The university collaborated with an urban development project aiming for creativity development-based community building, and after the design of an art and tech knowledge hub and space and its mobile outlets' exhibition and service design, the spring semester tackled the actual knowledge of playful creativity development.

This time, in the framework of the PUNTE project, the focus was on the cognitive games' creativity development and increasing their community-building potential. The Experience Workshop and its designers offered the games that served as the basis for the redesign. The students were given multiple cognitive game inventions to take a closer look at. Poly-Universe was one of them. The objective of the course was to create a complex game powered by playful mechanics based on the invention itself for the purpose of STEAM education-based creativity development.

The idea was to use creativity development through edutainment in a way that fosters community building, hopefully showing the potential to even become a hype. By hype, collective creative output

potential is meant, initiated from a gameplay or solution creating a possible fanbase and engaging shared content material. For the latter purpose, the Rubik Cube championships and the mosaic-like visual expressions to be found across the internet were a great inspiration, elevating the iconic game and the creativity it may unleash to another level. At the point when the course incorporating this novel concept was prepared for student enrollment, a global phenomenon emerged with the New York Times' acquisition of Wordle, a word guessing game resembling Mastermind featuring a daily global riddle in our shared virtual realm. The game's straightforward mechanics, appealing name, comprehensive statistics, and visually appealing outcome presentation have garnered significant attention and sustained user engagement. This is achieved through the interplay of players, facilitated by the seamless sharing of visual messages, as well as the addictive nature of regularly returning to the website for new riddles. The game's popularity has even prompted Google to develop a dedicated animation for the "Wordle" sub-site within their search results. But this was just the first phase of what felt like the Wordle 'momentum'. Soon, the game's clones appeared, ranging from simultaneous gameplays (e.g. Quordle, a version where one can guess four words at the same time) to language iterations and modality versions measuring arithmetic skills (Nerdle) to visual memory and geography (Worldle), to mention a few. Likewise, the cognitive game inventions of the Experience Workshop showed some memorable visual traits and combinatorial aspects to tap into and build on during the redesign.

Course Structure: A Three-Module Approach

The structure of the course, whether it is product idea research or a product redesign-focused theme, consists of three modules throughout the 28 classes of the semester. The first and second modules span the first quatrimester, while the third module concludes the first two, taking up the second quatrimester of the academic period concerned. The fourteen-week-long challenge starts with a research phase, executed in deliberately chosen teams of 2-4 students. The research topics are as numerous as the teams of the whole group of 12–17 and can be chosen from a list by any student independently.

Not only does this phase give freedom of choice, but throughout the whole course, the team choice is deliberate, based on the ideas and/or interests of each student. If the case calls for it, some primary research—typically an expert interview—can sometimes complete the desktop research. This research module lasts 3–4 weeks, and the teams present the findings to each other in class, contributing to an ever-expanding knowledge base that the students can explore. This knowledge base had its first foundation in the academic year 2019–2020, when the first mentioned course (tackling cooperative board games) took place. The students of each semester's course had access to the collective knowledge available from the related courses beforehand. This, combined with the fact that 10 students continued their studies during consecutive semesters on our course, allowed the new-found 'community' of students to have the environment of a 'lab' in the sense of finding the building blocks they can start their research and experiments with, gaining creative confidence and a deeper understanding of the concerned urban development project and the PUNTE project as much as the five courses' scope as a whole.

This collective knowledge base was complemented during the 2020–2022 academic years with further five courses in Hungary and globally (the four global ones realized online), as well as three student internships and five theses based on the courses' research domains, contributing with innovations to the innovative potential of the curriculum as well as the development project and the collaborations within. The research phase of each course concludes with a show-and-tell event where the students share the main aspects of the exploration of their desktop research recommended for consideration throughout the design process. During these first four weeks, the students have already started thinking about the design idea they'd like to deliver for the seventh week's show-and-tell occasion. This process is an individual one, contrasting the research task's team spirit and giving the students the opportunity to shift from the confidence and practice of teamwork and its effectiveness and possible urgency to the

digestion of the information load they encounter and deepen their focus and knowledge on a specific subsegment of the collectively examined and detailed problem space.

They each have seven weeks altogether (the first quadrimester itself) to come up with one or two ideas that solve the task in their own preferred way, concluding in a potentially innovative product design concept. The classes serve as a safe, interactive space for sketching, benchmarking, and consulting with the teachers about any ideas and thoughts preceding the final concepts, giving the students enough time to process the newly found information and reflections and iterate the concepts accordingly. The seventh week is the time of the second show-and-tell event where the students expose their ideas, potentially two if the time frame allows. Usually, for this occasion, a couple of stakeholders are invited from the project—domain experts and business professionals—who know exactly how to further develop the concepts to position them on the market as fresh innovations. This is the moment where students elaborate their presentation and the accompanying documentation of their research and concept ideas, so they get a sneak peek of what their peers are working on, with the opportunity to know the liked ones in depth, if required. All the documents are becoming part of the aforementioned knowledge base, hence being available to all working on the semester's project. After this session, the best ideas are chosen by the teachers and the experts, creating idea groups that the students can gravitate to once they have a preference for their following orientation.

Usually on a course, there are five to six directions to choose from, and students are again free to choose their path. Most likely, this choice comes with the stake of a certain team mix, so the final product concept will be developed together, in teamwork, accordingly. Any student is able to offer a developed idea of the first quadrimester on the presentation for further development, but the most complex and innovative ones might be the ones to be chosen as orienting ones for the mentioned five or six. One has the right to withdraw an idea if they are not willing to share its future with the teams; it is obviously an opt-in situation. When the main idea paths and the joined teams are established, the students are encouraged to explore the ideas and idea drafts of their peers from the first quarter and make a comparative analysis of them, understanding more deeply their relationships and the factors that might weigh in when evaluating a game throughout the process.

This leads to a more objective viewpoint for peer review and allows the students to create a vision based on the brief and some expertise they realize they have acquired along the way. The wide array of aspects enlisted by the groups in this module enables a complex *modus operandi*: it creates a system where viable, durable ideas can be the only ones that survive. Due to its fairly objective nature, the system doesn't incline towards the loudest or most ambitious student; it needs to be balanced and create equity. The moment is crucial for the decision. It confers with the Double Diamond design process model's divergent and convergent phases transition: the naming and the main attributes to be determined collectively.

The Double Diamond design process is a widely recognized model that describes the design process in four distinct phases: Discover, Define, Develop, and Deliver. These phases are visually represented by two adjacent diamond shapes, symbolizing the divergent and convergent thinking stages of the process. In the context of STEM and STEAM education, the Double Diamond process has been applied to foster creativity, critical thinking, collaboration, and problem-solving skills (Lin, 2011). In the Discover phase, the focus is on exploration and research. This aligns with the inquiry-based learning approach in STEM and STEAM education, where students are encouraged to explore scientific concepts and phenomena through observation and experimentation (National Research Council, 2012). The Define phase involves analyzing and synthesizing insights to define a specific problem or challenge. In STEM and STEAM education, this phase emphasizes the importance of defining clear research questions and hypotheses, fostering analytical thinking and scientific reasoning (Honey et al., 2014). The Develop phase encourages creative and collaborative idea generation. In STEM and STEAM education, this phase supports project-based learning, where students work together to develop innovative solutions to real-world problems (Bell, 2010).

Finally, the Deliver phase focuses on the implementation of the solution. In the context of STEM and STEAM education, this phase emphasizes the application of scientific knowledge and engineering principles to create tangible products or solutions (Bybee, 2013). The Double Diamond design process provides a structured yet flexible framework that aligns well with the goals of STEM and STEAM education. By alternating between divergent and convergent thinking, it encourages a balanced approach that integrates scientific inquiry, creativity, collaboration, and practical application. Its application in educational settings reflects its versatility and effectiveness in guiding the learning journey (Sanders & Stappers, 2008; Lin, 2011).

The following steps stem from here, establishing the mechanisms through constant testing and iteration. Once the game concept has a character, the next task is to keep track of its usability and desirability, along with any potential further design principles considered. These steps basically occupy all the remaining weeks of the semester, along with the creation and iteration of the physical prototype, of course. Once everything is playtested and the rules are also dumbproof, the last show-and-tell event may start. On this occasion, the designated hall is also prepared; the prototypes are there in real size for the guests and fellow course members to try out. It is a special moment for each team and all the students present to generate an 'aha' and 'awe' moment among their peers. The discussions after the presentations continue way into the lunch break with the expert guests and stakeholders about further opportunities, usually. It is a full cycle, from research to exploration and creation to new horizons of possible exploration and refinement.



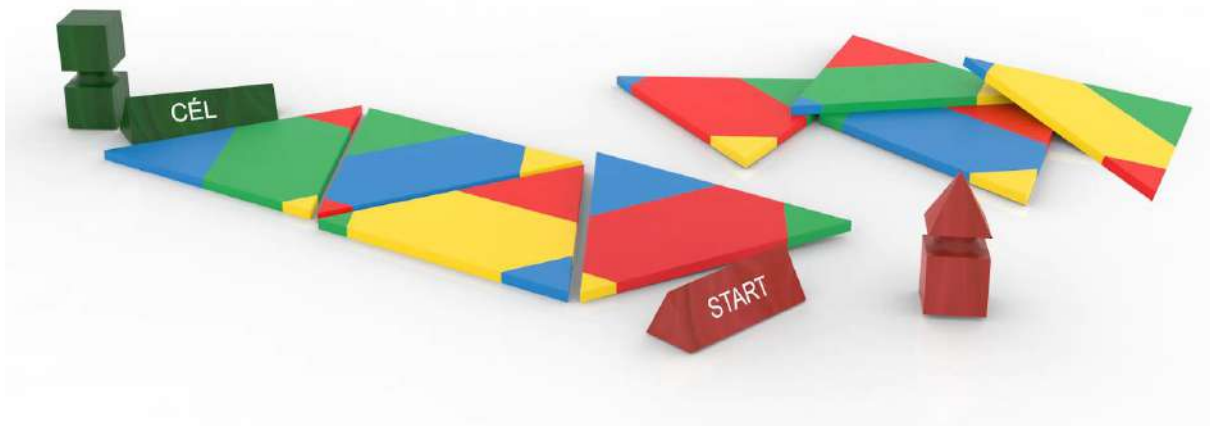
Course session with experts, including Poly-Universe inventor János Szász Saxon and Zsuzsa Dárdai from the PUNTE project (in the middle)

Poly-Universe: A Case Study in Innovation

Poly-Universe was among the most popular cognitive game inventions of the Experience Workshop due to its two-dimensional and limitless visual building potential. The students were eager to try out all the ideas they could conceive, connecting it with past board game and card game experiences; it might even serve as a certain kind of visualization for abstract notions and phenomena. It let imagination go wild, and deep examination followed its introduction. Since it had a few recommended mechanics for consideration but a relatively open ‘framework’ of rules for placement, the students explored combinations of multiple packages and color palettes, creating new boundaries and connotations for the patterns, symmetries, and elements we may encounter along the gameplay.

Here are some of the innovative ways the participants and their teams reimagined the invention:

Ferry:



Designer: Csenge Adorján

- Competitive strategy game
- Flexibility
- Actions, like ‘turning a piece over’
- Travel-size

Number of Players: 2 (age 7+)

Playing time: 10-20 mins

Kingdom of Saxon:



Designer: Kristóf Faludy

- Strategy game
- Cooperative or competitive mode
- Scalable
- Personalization: Castle
- 3D printed figures

Number of Players: 2-4 (age 10+)

Playing time: 10-20 mins

Eder:



Designer: Benedek Szlama

- 3D, icosahedron
- Magnetic placement

- Well-fit in a hand
- ‘Travel kit
- 3D printing
- Marketing value (merchandising potential)

Number of Players: 1-2 (age 8+)

Penrose Panda:



Designer: Gábor Karosi

- Roger Penrose
- 3D printing
- Iterations – e.g. map of France

Hattori:



Designer: Gábor Karosi

Number of Players: 1-2 (age 8+)

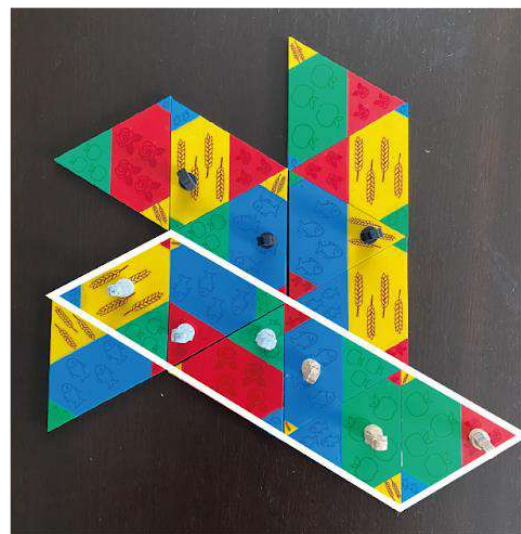
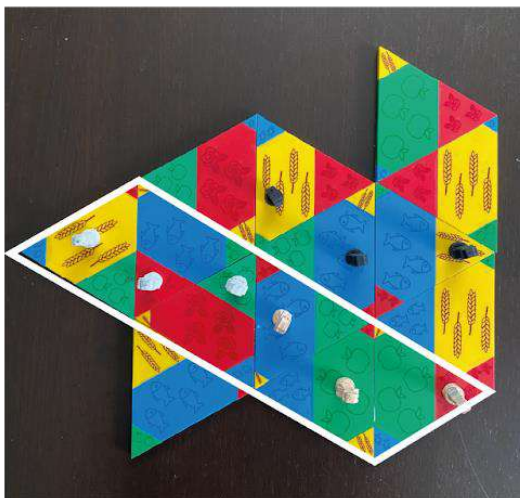
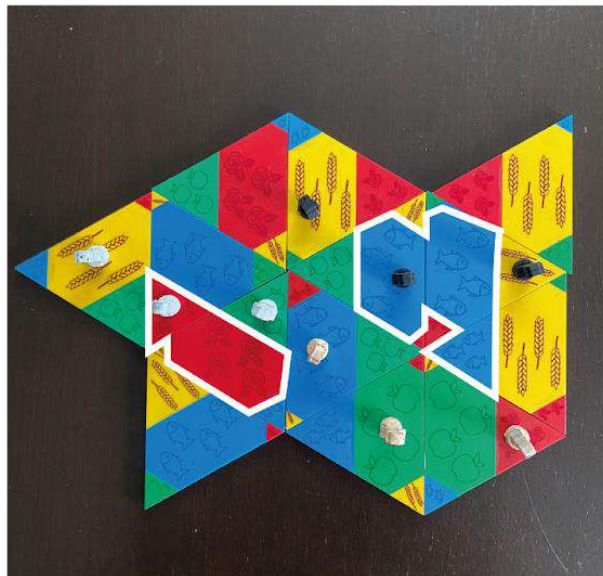
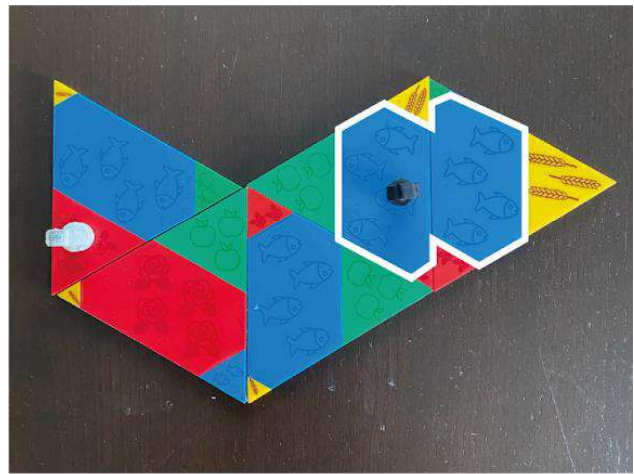
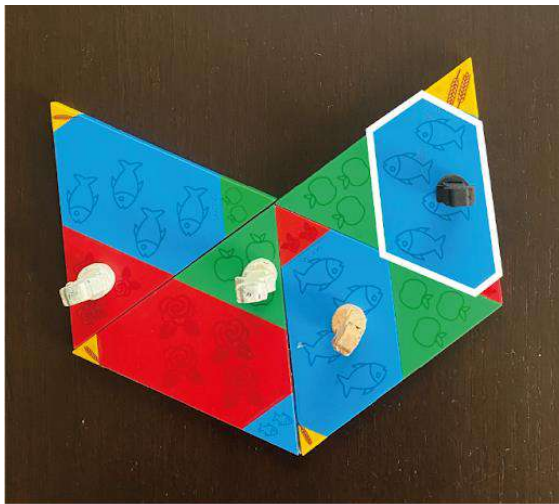
Playing time: 15-30 mins

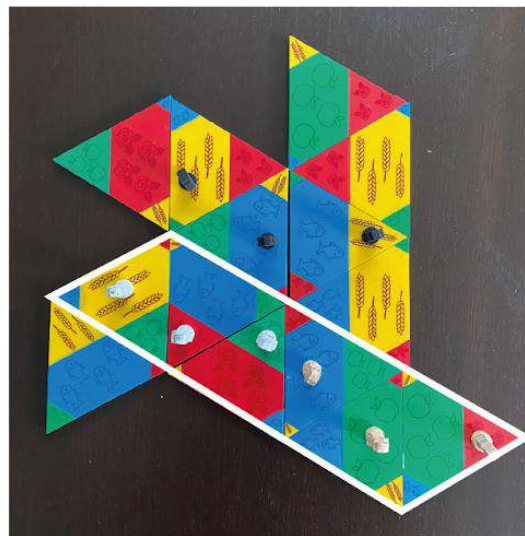
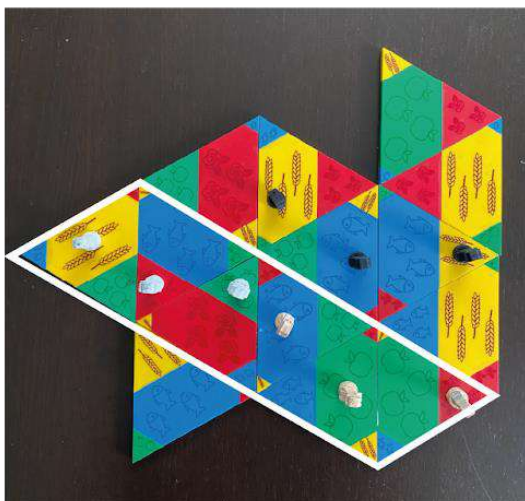
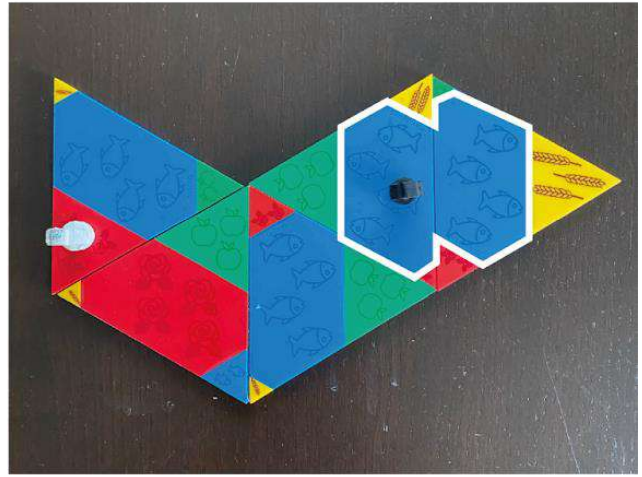
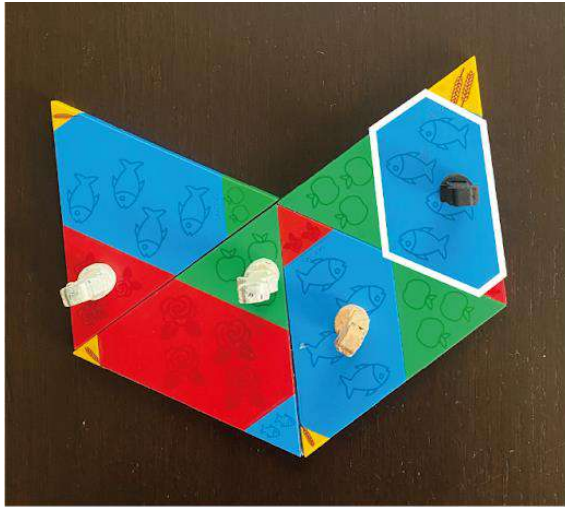
Story Universe:

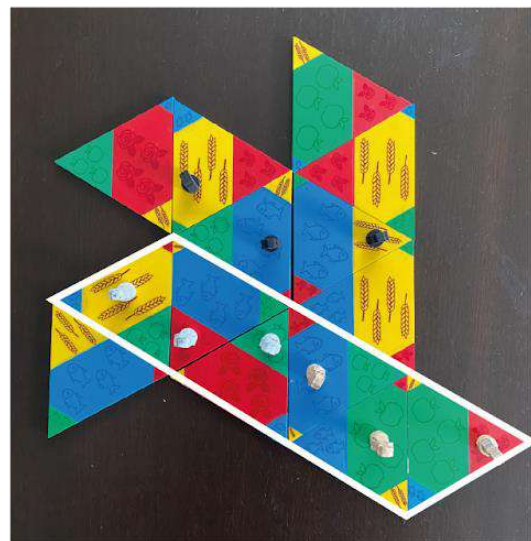
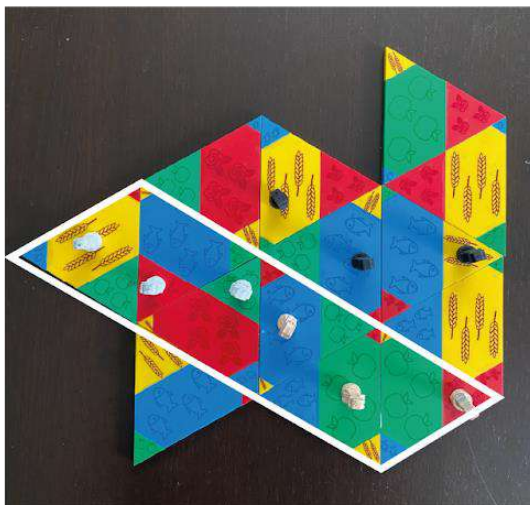
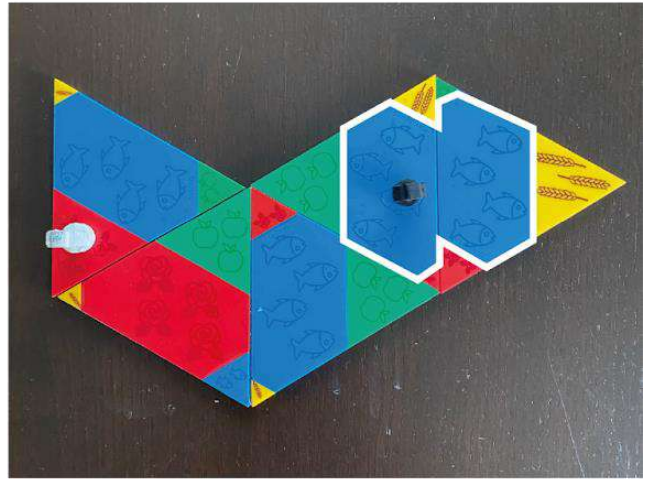
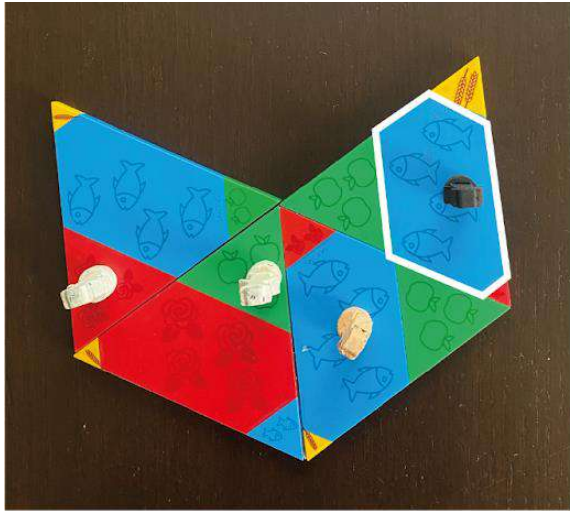


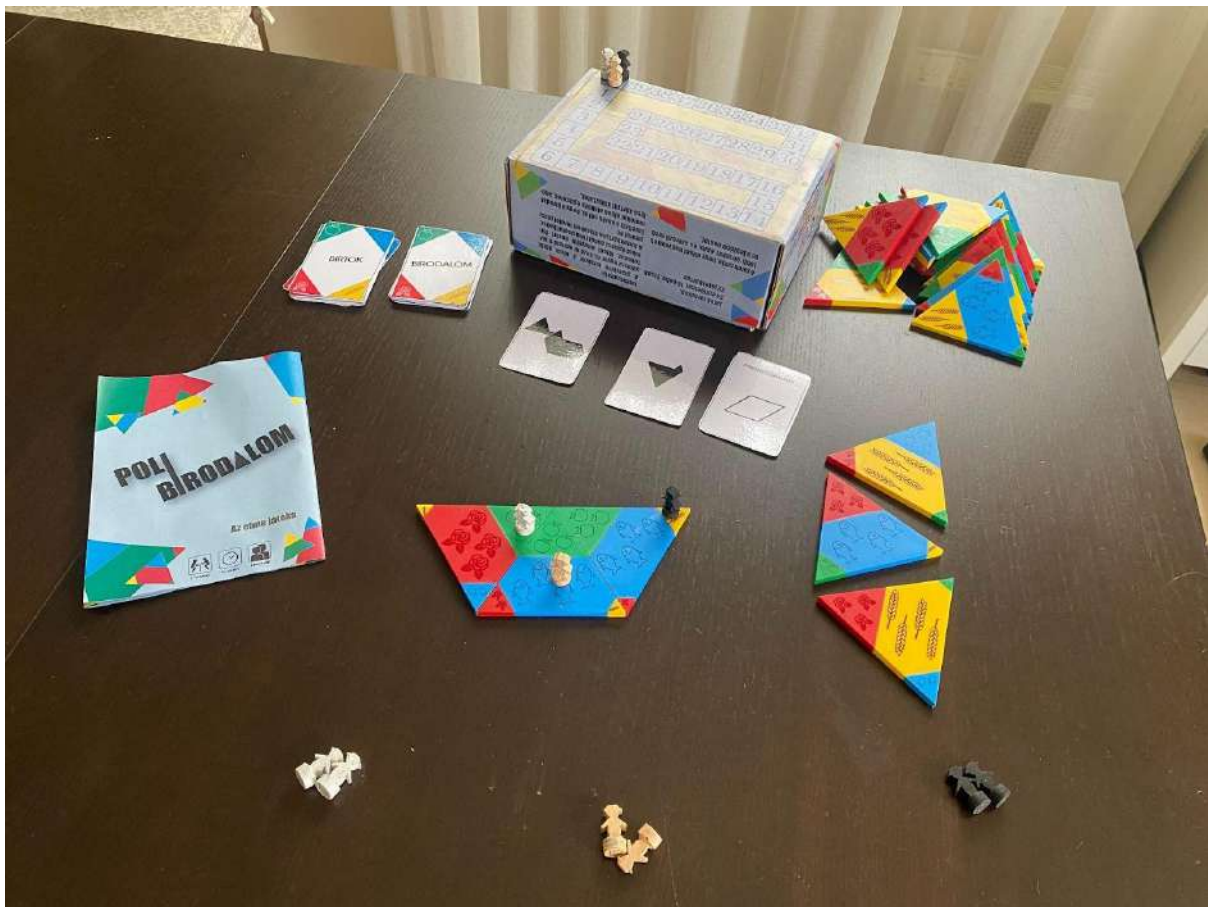
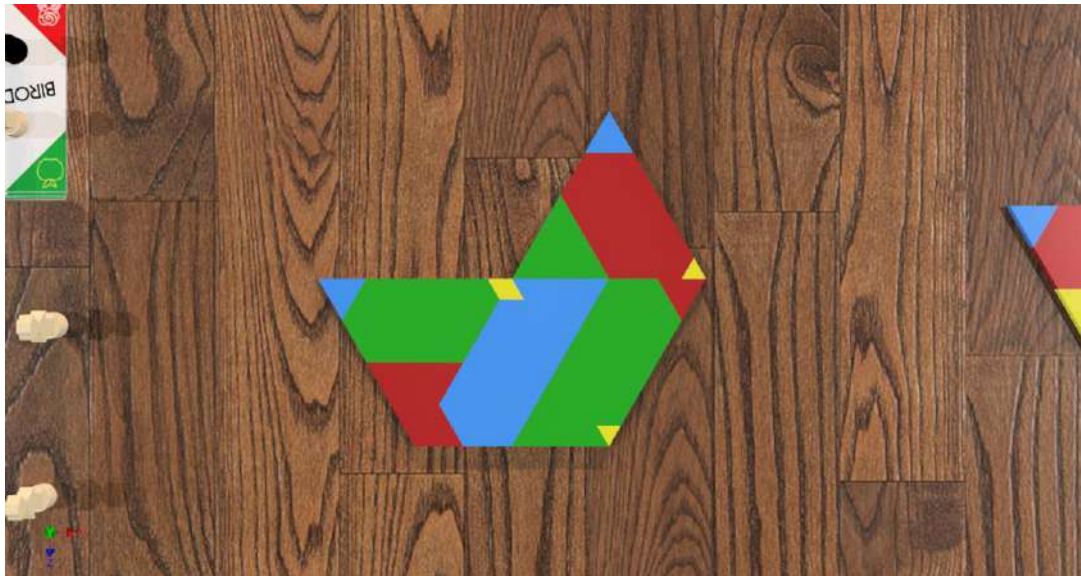
Designers: Levente Bálint, Zsombor Égerházi, Kristóf Faludy, Csenge Mező

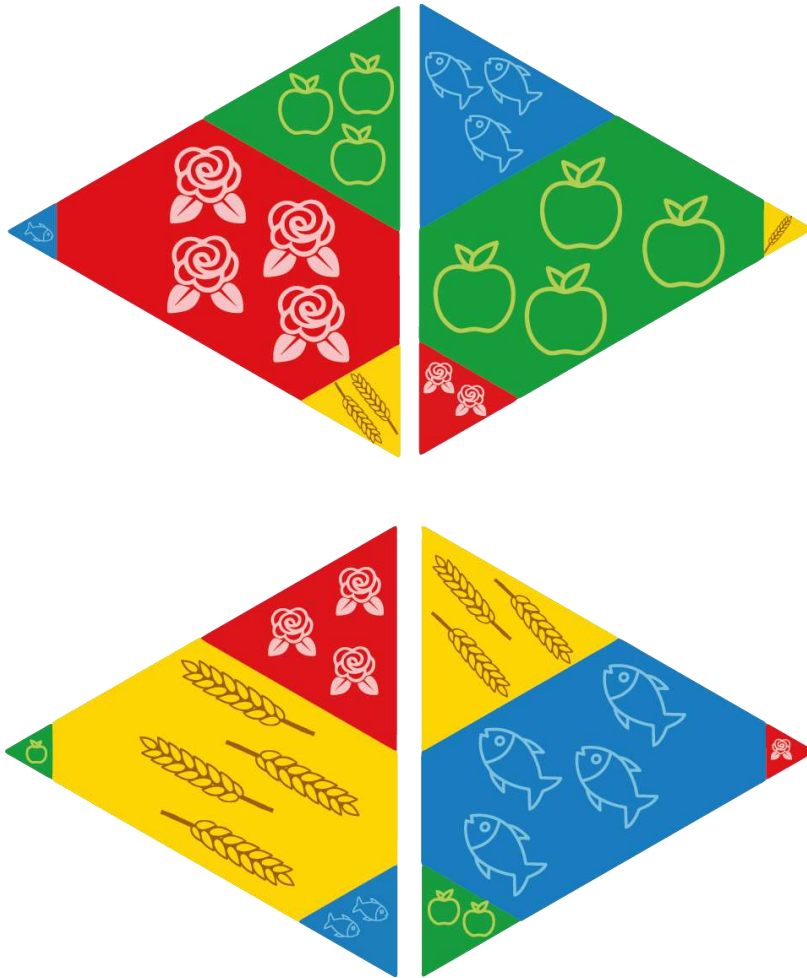
PoliEmpire











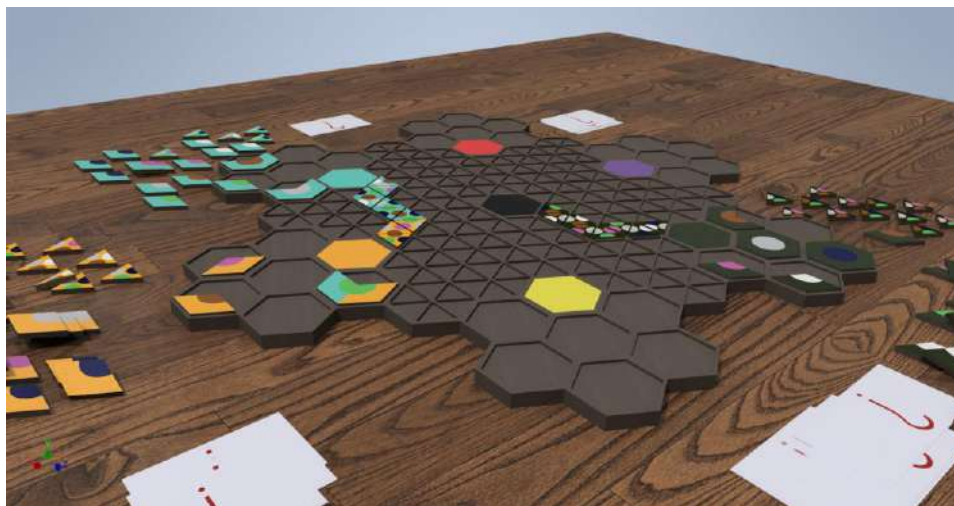
Designers: Noémi Apró, Réka Erdős, Viktória Slezák

- Territory occupation
- Marketplace
- Tile-shift
- Cards
- Score track
- Agriculture theme
- Printed adhesive foil, laser cut figures, magnets

Number of Players: 2-4 (age 8+)

Playing time: 15-30 mins

PolyVia:



Designer: Réka Erdős

Number of Players: 2-6/group, 14+

Playing time: 60-120 mins

References:

- Becker, K. H., & Park, K. (2011). Integrative approaches among science, technology, engineering, and mathematics (STEM) subjects on students' learning: A meta-analysis. *Journal of STEM education: Innovations and research*, 12(5).
- Bell, S. (2010). Project-Based Learning for the 21st Century: Skills for the Future. *The Clearing House: A Journal of Educational Strategies, Issues and Ideas*, 83(2), 39-43.
- Bybee, R. W. (2013). The Case for STEM Education: Challenges and Opportunities. *NSTA Press*.
- Gee, J. P. (2003). What video games have to teach us about learning and literacy. *Computers in entertainment (CIE)*, 1(1), 20-20.
- Gee, J. P. (2007). Good video games+ good learning: Collected essays on video games, learning, and literacy. *Peter Lang*.
- Honey, M., Pearson, G., & Schweingruber, H. (2014). STEM Integration in K-12 Education: Status, Prospects, and an Agenda for Research. *National Academies Press*.
- Kapp, K. M. (2012). The gamification of learning and instruction: game-based methods and strategies for training and education. *John Wiley & Sons*.
- Land, M. H., et al. (2014). Full STEAM Ahead: The Benefits of Integrating the Arts Into STEM. *Procedia Computer Science*, 20, 547-552.
- Lin, Y. S. (2011). Fostering creativity through education—a conceptual framework of creative pedagogy. *Creative education*, 2(03), 149.
- National Research Council. (2012). A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas. *The National Academies Press*.
- Prensky, M. (2006). Don't bother me, mom, I'm learning!: How computer and video games are preparing your kids for 21st century success and how you can help!. *St. Paul, MN: Paragon house*.
- PUNTE Study – Poliuniverszum a Tanárképzésben. Módszertani tanulmány. Kézikönyv gyakorló tanárok és pedagógus hallgatók számára: ISBN 978–606–9673–42–3 (nyomtatott verzió), ISBN 978–606–9673–43–0 (online kiadás) <https://www.punte.eu>, Partium Kiadó, 2022 Oradea–Nagyvárad, 2023.
- Quigley, C., & Herro, D. (2016). “Finding the Joy in the Unknown”: Implementation of STEAM Teaching Practices in Middle School Science and Math Classrooms. *Journal of Science Education and Technology*, 25(3), 410-426.
- Sanders, E. B. N., & Stappers, P. J. (2008). Co-creation and the new landscapes of design. *CoDesign*, 4(1), 5-18.
- Szász SAXON, J., Stettner, E., eds. (2019) PUSE (Poly- Universe in School Education) METHODOLOGY –Visual Experience Based Mathematics Education, Szokolya: Poly- Universe Ltd. 2019. Open access in pdf from <http://poly-universe.com/puse-methodology/> 254 p., ISBN 978-615-81267-1-7.