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"It looks like my die has a favorite number"—maker education for 21st century skills in primary science education

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This paper explores the integration of Maker Education into primary schools and its potential to foster essential digital and interdisciplinary skills. Grounded in constructivist and constructionist theories, Maker Education emphasizes hands-on, project-based learning using traditional and digital tools, particularly 3D design and printing, enabling learners to actively design, build, and iterate their own. The paper draws on practical examples from German-speaking countries, including a detailed classroom project in which primary students used TinkerCAD to design and analyze 3D-printed dice. The implementations are characterized by flexible, open-ended learning environments that support inquiry-based and collaborative learning, even with limited resources. The examined cases indicate positive effects on student motivation, engagement, and competence development. Students developed skills in geometry, mass distribution, digital fabrication, and scientific inquiry, particularly when learning activities were connected to real-world problems and collaborative making. Maker Education supports the development of 21st-century competencies such as creativity, critical thinking, communication, and digital literacy. However, its sustainable implementation requires addressing curricular constraints, technical demands, and the need for systematic integration of maker pedagogies into teacher education.

KEYWORDS

3D-modeling, 3D-printing, future skills, maker education, primary school

Introduction

Maker Education describes a learning approach grounded in hands-on creation and tinkering, where learners design their own projects using analogue and digital tools. Instead of passively receiving knowledge, children become active creators who iteratively design and refine prototypes (Ingold and Maurer, 2020, 2024; Martin, 2015). This approach builds on constructivist and constructionist perspectives (Harel and Papert, 1991), which emphasize that learning becomes particularly effective when learners build tangible objects (Piaget, as discussed in Bliss, 1996; Papert, 1991; Romeike, 2011; Stilz et al., 2020). In primary schools, maker activities enable interdisciplinary learning that integrates scientific experimentation, technological design, artistic choices, and collaborative reflection (Stiller et al., 2023; Martínez Moreno et al., 2021). Research shows that such projects can strengthen creativity, media literacy, self-efficacy, and persistence in problem solving (Halverson and Sheridan, 2014; Blikstein, 2018; Iwata et al., 2020; Wang et al., 2025). At the same time, schools face challenges such as limited time structures, lack of technical infrastructure, insufficient teacher training,

and the risk of students engaging only in superficial tinkering without guidance (Hira et al., 2014; Hughes and Kumpulainen, 2021; Nemorin, 2017).

Although maker education is not yet a standard in all elementary schools, practical examples in German-speaking countries show that it can be integrated into everyday school life with either simple tools or high-tech equipment (Stilz et al., 2020). Some schools begin with small-scale, low-threshold initiatives, such as temporary workshop corners that combine craft materials, LED circuits, or basic coding tools like the Calliope mini (Bildung.digital, 2025; Stilz et al., 2020). Others have established permanent maker spaces connected to real-world activities, such as producing spare parts or printed textiles to support student-run mini businesses (Bildung.digital, 2025). Research-based implementations, such as the Thayngen primary school project in Switzerland, demonstrate that sustainable integration depends on leadership support, flexible time structures, and cooperation with external partners (Ingold and Maurer, 2021).

These examples illustrate the potential of maker education to support exploratory, creative, and interdisciplinary learning, but they also highlight the pedagogical challenge of scaffolding open-ended tasks to avoid superficial “tinkering” and to ensure meaningful reflection (Halverson and Sheridan, 2014). This balance between autonomy and guidance raises questions about how young learners actually engage with digital modeling and physical prototyping when offered open workshop conditions.

Despite increasing attention in research, empirical insights into how primary students design, reason about, and learn from digital fabrication processes remain scarce. Small, well-defined maker activities, such as 3D-printing customized dice, offer a promising context to investigate children’s creative decisions and their emerging understanding of geometry, balance, fairness, and material properties.

Research questions

RQ1: How do children design their own 3D-printed dice in an open maker setting?

RQ2: How does this design process demonstrate early creative problem-solving in geometry, balance, or symbolism?

Method

Research design

The study used an artifact-based mixed-methods approach grounded in constructionist and design-based learning principles. Students’ 3D-printed dice were treated as tangible manifestations of ideas developed during the design process. Physical artifacts and classroom observations were analyzed as primary data sources to investigate how students reasoned about geometry, fairness, and balance in an open maker setting. Similar approaches have been used to investigate learning through the artifacts students produce (Azizan and Shamsi, 2022; Quintana-Ordorika et al., 2024).

Participants and setting

Data were collected during a primary school enrichment course with 19 students and a holiday maker program with 12 students, resulting in a total of 31 student-created dice. Students were in grades three and four and worked either in a school classroom or a designated maker space. Across approximately 6 h of learning time (either as six sessions of 40 min or as a one-day workshop), students completed a design challenge using TinkerCAD. To introduce the software, the “one” face of the die was modeled together using a single dot. After this demonstration, students independently designed the remaining five faces based on their own ideas. After printing, dice were tested through repeated rolling (see Figure 1) and mass measurement. During the sessions, non-participant observations were carried out, and student interactions, explanations, and design choices were documented through field notes and written summaries.

Materials and digital tools

Students worked with TinkerCAD as an entry-level CAD tool. Designs were exported through a teacher account and prepared for printing using Cura. All dice were printed with identical parameters (same material, 30% infill, grid pattern, see Figure 2) so that observed differences in rolling behavior (see Table 1) could be attributed to design choices rather than production differences. A 3D-printed dice tower supported standardized testing during experimentation. Worksheets helped students document design features, tallies of rolled values, and potential explanations.

Artifact-based analysis and coding

Printed dice were analyzed as learning artifacts that reflected individual decision-making in TinkerCAD. The analysis followed an inductive thematic coding approach (Braun and Clarke, 2006). Each die’s faces and features were examined, recurring patterns were noted, such as dot arrangements, text elements, symbolic designs (e.g., stars, hearts, football shapes), or numerical representations using digits or equations. Based on these observations, an initial set of codes was developed for high-level categories (e.g., numeric symbols, text labels, decorative shapes), drawing on research that treats artifacts as indicators of thinking (Jones and Worrall, 2025; Liljedahl, 2017). Additional categories emerged from the data itself, including personal names, family references, geometric embellishments, minimal modification, weighted features, and redesign traces. The resulting codes (see Table 2) included categories such as Dot Patterns, Alphanumeric Labels, Personal Symbols, Illustrations, and Geometric Embellishments, and codes were refined inductively as new distinct details appeared. Frequencies were tallied and exemplars were documented to illustrate each category.

Qualitative findings: faces individuality

The first side with one dot for “one” was made together, to introduce the students into TinkerCAD and its features and is therefore the highest number in Figure 3. The other five sides were free to use as the students pleased. The dice were looked at and the different features found documented.

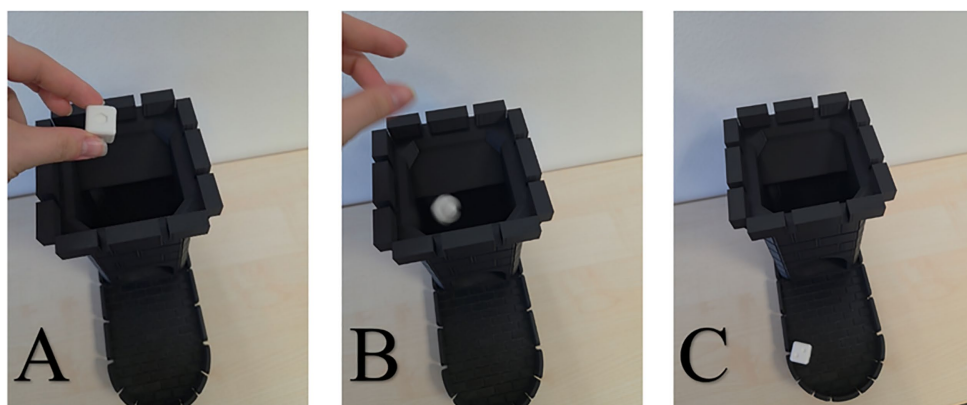


FIGURE 1

Rolling with a dice tower to ensure consistent randomized rolling behavior. (A) positioning the die over the dice tower. (B) Die falling into the dice tower. (C) Die after rolling through dice tower.

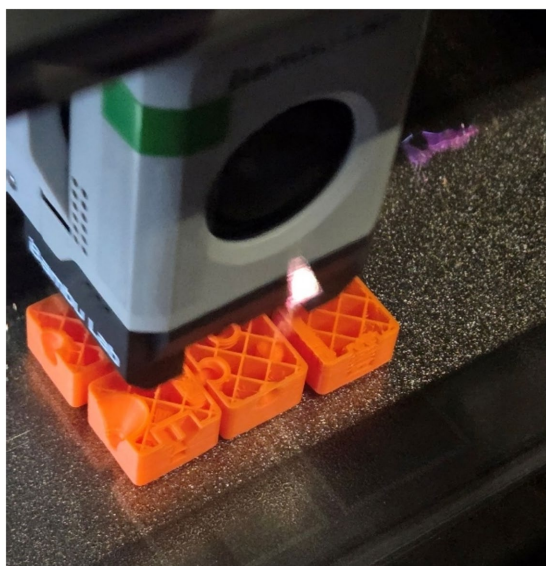


FIGURE 2

3D-printing the student made dice. It shows that the dice are all different even if the print parameters are the same.

It shows that the students designed the different faces very individually. Shapes (21), numbers as numbers (16) or numbers as text (3) as well as geometric figures used for dots (5) were preferred. Also, their own names or names of family members were found on the faces of the dice. Some students also used mathematical equations like additions to symbolize numbers (e.g., $5 + 1 = 6$) or used numeric rows like 12,345 on one face and 123,456 on another. These were also sorted under the category “Numbers (as in ‘4’)”

Quantitative data and analysis

Masses of the printed dice varied from 4.00 g to 5.84 g ($M = 5.00$ g; $SD = 0.34$), despite identical printing parameters. This variation reflected differences in engraving depth, symbol density, and wall

thickness created by students. Rolling frequencies showed uneven distributions. The students engaged with these phenomena using tally charts and class discussion, forming explanations about how design features affected fairness and balance. These quantitative observations supported early cause-and-effect reasoning in physical systems. The students documented their findings in a work sheet, which was used in the qualitative analysis of 21st century skills (see Figure 4).

Observation coding for 21st-century skills

Observations focused on creativity, critical thinking, communication, collaboration, digital literacy, and self-efficacy. For example, hypotheses such as “maybe one side is heavier” were coded under critical thinking, while “I made stars because they bring luck” illustrated creative expression. Collaborative testing and peer explanation were coded as communication, and confident interaction with TinkerCAD reflected digital literacy. Expressions like “I think I should improve my die” were coded as reflective learning and self-efficacy (see Table 2). This procedure aligns with frameworks emphasizing transferable competencies in maker education (KMK, 2016; Ingold and Maurer, 2024).

Triangulation and validity

Artifact analysis was compared with corresponding observations and student statements. For each student, visible design choices were cross-referenced with verbal explanations and testing behavior. Peer debriefing supported coding consistency, and reflective notes documented analytic decisions. The approach aligns with findings that artifacts and interaction combined can reveal learning processes in constructionist environments (Quintana-Ordorika et al., 2024).

Results

RQ1 concerned how children design dice in an open maker setting. The printed dice were highly individualized. Students integrated symbols such as stars, hearts, and smileys, used

TABLE 1 Sample results after about 40–60 rolls, print screen from scans.

Augenzahl / Text	Wie oft gewürfelt?	insgesamt
Josephine		29
Love		12
Ike		20
8		14
♥		25
○		18

Augenzahl / Text	Wie oft gewürfelt?	insgesamt
Herz		14
Mira		13
Krei		11
totenkopf		14
Zampe		1
? Frage		17

Augenzahl / Text	Wie oft gewürfelt?	insgesamt
Marvin		8
Dennis		9
Karim		12
Jaschp		6
Kreis		12
Fußball		19

Augenzahl / Text	Wie oft gewürfelt?	insgesamt
Karin		17
Dennis		10
Joseph		6
Kreis		17
Zylinder		17
Fußball		19

Augenzahl / Text	Wie oft gewürfelt?	insgesamt
Eine 6		7
3		7
TOMATE		3
1		11
die 4		8
Stern		4

Augenzahl / Text	Wie oft gewürfelt?	insgesamt
Tolu		9
67		9
Oh		16
Pesh		16
Glück		16
•		23

TABLE 2 Triangulation of artifact-based code, observation and evidence of data to identify 21st-century-skills (Andrews et al., 2021; Azizan and Shamsi, 2022; Bower et al., 2018; Hsu et al., 2017; Kafai et al., 2014; Soomro et al., 2023; Taylor, 2016; Unterfrauner et al., 2021; Papavaslopoulou et al., 2017; Sheridan et al., 2014).

Artifact-based code (dice characteristics)	Observation-based code (student behavior/ statements)	Evidence from data (transcribed examples)	Triangulated 21st-century skill
Non-standard symbolic faces (e.g., stars, hearts instead of dots)	Verbal reflection on meaning of symbols	"I made the 6 with stars instead of dots because stars are lucky." (Nina)	Creativity & Innovation
Asymmetrical hole depth/large engraved shapes	Hypothesis about mass and rolling behavior	"I think the number 3 keeps showing up because the circle on that side is really big." (Luca)	Critical Thinking & Problem-Solving
Personalized text/letter engravings	Explanation of design purpose	"It's fun because my die spells a word when I roll it three times." (Sophie)	Creativity & Communication/ Collaboration
Balanced design with uniform shapes on faces	Self-assessment of fairness	"My die is fair, I think, because all the numbers came up about the same." (Elias) "It looks like my die has a favourite number." (Ben) "Maybe one side is heavier than the others." (Emilia)	Analytical Reasoning + Reflective Learning
Evidence of redesign intention (student comments about improvement)	Metacognitive planning	"I think I should improve my die." (Lina)	Self-Efficacy & Reflective Learning
Deep recesses/heavy symbolic engravings	Discussion of internal structure	Classroom discussion about wall thickness and infill during dice tower testing	Digital Literacy & ICT Competence
Use of non-traditional opposite-face arrangements	Independent rule-breaking/ exploration	Students deliberately ignored traditional 1–6 / 2–5 / 3–4 opposite face structure	Creativity + Divergent Thinking
Complex shapes built in TinkerCAD (e.g., free hand drawings)	Strategic tool use	Observed use of grouping, rotation, and Boolean "hole" tools	Digital Literacy & Technical Fluency

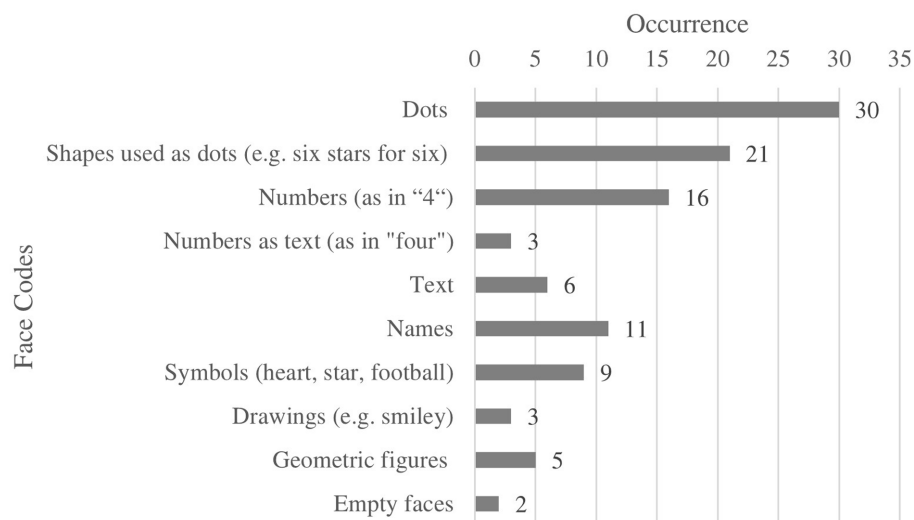


FIGURE 3
Qualitative coding of the individual dice faces. Counting of occurrence of face codes.

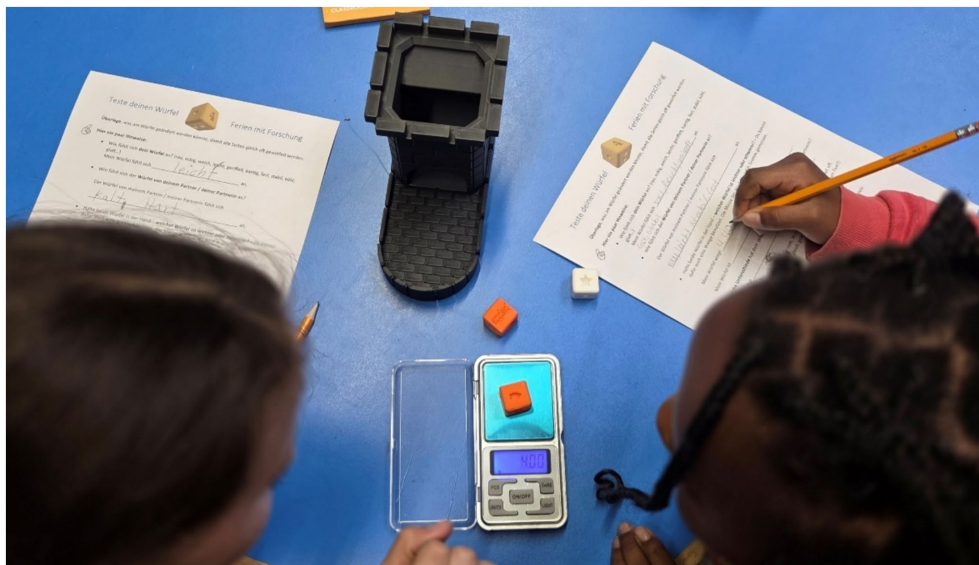


FIGURE 4
To test their own dice, students were encouraged to roll them many times and document the outcome. Here, the die is weighed.

numbers or words, and sometimes wrote equations like “ $5 + 1 = 6$.” Some dice included names or objects, and the traditional arrangement of opposite faces was frequently ignored. One student explained: “I made the 6 with stars instead of dots because stars are lucky.” Another commented: “It spells a word if I roll three times!”

RQ2 focused on creative problem-solving in relation to geometry, balance, or symbolism. Students connected rolling outcomes to features of their dice. Comments included: “Maybe one side is heavier,” “It looks like my die has a favorite number,” and “The circle on the 3 is big; maybe it’s heavier there?” Mass measurements supported these

ideas, as dice varied in weight and deeper recesses or larger symbols influenced roll frequency. Some students suggested improvements based on testing, as one remarked: “I think I should improve my die.”

Discussion

The students acted as designers, testers, and improvers, reflecting principles of maker education such as autonomy, iteration, and a positive error culture (Ingold and Maurer, 2024). Their reasoning about geometry and imbalance resembled early scientific inquiry, and

personal design choices became objects of investigation when the dice behaved unexpectedly. Creative expression and analytical thinking worked together and not against each other.

The activity supported competencies associated with creativity, critical thinking, communication, collaboration, digital literacy, and reflective learning, consistent with competency frameworks and research in constructionist settings (KMK, 2016; Stilz et al., 2020). Students used symbols with personal meaning, generated hypotheses, helped each other with CAD tools, and demonstrated confidence in improving their work.

The project also highlighted challenges for implementing maker projects. Some students initially focused only on decorative aspects without considering functional effects. Teacher support was important for guiding scientific inquiry. Educators therefore need both technical preparation and pedagogical strategies to scaffold open-ended, inquiry-based design tasks (Hira et al., 2014; Nemorin, 2017).

Conclusion

Designing and printing personalized dice provided a low-threshold opportunity for primary students to engage with geometry, digital fabrication, and experimental testing while expressing personal ideas. The activity encouraged creative decision-making, analytical reasoning, and iterative improvement. These results show that maker education can support early STEM learning through meaningful, personally relevant tasks rather than predetermined exercises.

Looking forward, sustainable implementation requires teacher education programs and schools to provide time structures, access to fabrication tools, and pedagogical frameworks that support inquiry-driven making. If universities and policymakers invest in practical maker-pedagogy training and create pathways for teachers to adopt these approaches early, maker learning can become a future-oriented foundation for participation, agency, and innovation in STEM from the very beginning of schooling.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

Ethical approval was not required for the study involving human samples in accordance with the local legislation and institutional requirements. Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin. Written

References

- Andrews, M. E., Borrego, M., and Boklage, A. (2021). Self-efficacy and belonging: the impact of a university makerspace. *Int. J. STEM Educ.* 8, 1–18. doi: 10.1186/s40594-021-00285-0
- Azizan, S. A., and Shamsi, N. A. A. (2022). Design-based learning as a pedagogical approach in an online learning environment for science undergraduate students. *Front. Educ.* 7:860097. doi: 10.3389/feduc.2022.860097

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Supplementary material

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Bildung.digital. (2025). Einfach machen – Maker Spaces in der Schule. Forum Bildung Digitalisierung. Available online at: <https://www.bildung.digital/artikel/einfach-machen-maker-spaces-der-schule> (Accessed July 15, 2025).

Blikstein, P. (2018). "Maker movement in education: history and prospects" in Springer International Handbooks of Education. In M. de Vries, (Ed.), Cham: Springer. doi: 10.1007/978-3-319-44687-5_33

- Bliss, J. (1996). Piaget und Vygotsky. Ihre Bedeutung für das Lehren und Lernen der Naturwissenschaften. *Z. Didaktik Naturwiss.* 3, 3–16. doi: 10.25656/01:31493
- Bower, M., Stevenson, M., Falloon, G., Forbes, A., and Hatzigianni, M. (2018). Makerspaces in primary school-settings – Advancing 21st century and STEM capabilities using 3D design and 3D printing. Available online at: <https://primarymakers.com/static/primarymakers.files.wordpress.com/2019/06/makerspaces-in-primary-school-settings-full-report-2018v2.pdf> (Accessed July 15, 2025).
- Braun, V., and Clarke, V. (2006). “Using thematic analysis in psychology,” in *Qualitative Research in Psychology* 3, 77–101. doi: 10.1191/1478088706qp0630a
- Halverson, E. R., and Sheridan, K. (2014). The maker movement in education. *Harv. Educ. Rev.* 84, 495–504. doi: 10.17763/haer.84.4.34j1g68140382063
- Harel, I., and Papert, S. (Eds.). (1991). *Constructionism: Research reports and essays*. Norwood, NJ.
- Hira, A., Joslyn, C. H., and Hynes, M. M. (2014). Classroom makerspaces: identifying the opportunities and challenges. In *2014 IEEE Frontiers in education conference (FIE 2014): Madrid, Spain, 22-25 October 2014* (pp. 1–5). IEEE
- Hsu, Y.-C., Baldwin, S., and Ching, Y.-H. (2017). Learning through making and maker education. *TechTrends* 61, 589–594. doi: 10.1007/s11528-017-0172-6
- Hughes, J. M., and Kumpulainen, K. (2021). Editorial: maker education: opportunities and challenges. *Front. Educ.* 6:798094. doi: 10.3389/feduc.2021.798094
- Ingold, S., and Maurer, B. (2020). MakerSpace – Raum für Kreativität. Ein Design-Based Research-Projekt zur partizipativen Entwicklung einer Making-Lernumgebung in einer Primarschule. *Teil 2: Maker Education – Anliegen, Prinzipien, Praxis*. doi: 10.13140/RG.2.2.33324.49288
- Ingold, S., and Maurer, B. (2021). *Making im Schulalltag: Konzeptionelle Grundlagen und Entwicklungsschritte*. Munich: kopaed.
- Ingold, S., and Maurer, B. (2024). *Making und Schule: Praxishandbuch für Schulentwicklung und Unterricht*. Munich: kopaed.
- Iwata, M., Pitkänen, K., Laru, J., and Mäkitalo, K. (2020). Exploring potentials and challenges to develop twenty-first century skills and computational thinking in K-12 maker education. *Front. Educ.* 5:87. doi: 10.3389/feduc.2020.00087
- Jones, M., and Worrall, L. (2025). Using artefacts as a research method to explore effective mentoring in teacher education. *Practice* 7, 98–112. doi: 10.1080/25783858.2024.2424207
- Kafai, Y., Fields, D., and Searle, K. (2014). Electronic textiles as disruptive designs: supporting and challenging maker activities in schools. *Harv. Educ. Rev.* 84, 532–556. doi: 10.17763/haer.84.4.46m7372370214783
- KMK. (2016). *Bildung in der digitalen Welt: Strategie der Kultusministerkonferenz*. Available online at: https://www.kmk.org/fileadmin/Dateien/veroeffentlichungen_beschluesse/2016/2016_12_08-Bildung-in-der-digitalen-Welt.pdf
- Liljedahl, P. (2017). “Relationship between proxies for learning and mathematically related beliefs” in *Students’ and teachers’ values, attitudes, feelings and beliefs in mathematics classrooms: selected papers from the 22nd mavi conference*. eds. H. Palmér and J. Skott (pp. 1–11). Cham: Springer). doi: 10.1007/978-3-319-70244-5_1
- Martin, L. (2015). The promise of the maker movement for education. *J. Pre-Coll. Eng. Educ. Res.* 5, 30–39. doi: 10.7771/2157-9288.1099
- Martínez Moreno, J., Santos, P., and Hernández-Leo, D. (2021). Maker education in primary education: changes in students’ maker-mindset and gender differences. In M. Alier (Ed.), *ACM Digital Library, Ninth International Conference on Technological Ecosystems for Enhancing Multiculturality (TEEM’21)* (pp. 120–125). Barcelona, Spain: Association for Computing Machinery
- Nemorin, S. (2017). The frustrations of digital fabrication: an auto/ethnographic exploration of ‘3D making’ in school. *Int. J. Technol. Des. Educ.* 27, 517–535. doi: 10.1007/s10798-016-9366-z
- Papavlasopoulou, S., Giannakos, M. N., and Jaccheri, L. (2017). Empirical studies on the maker movement, a promising approach to learning: a literature review. *Entertain. Comput.* 18, 57–78. doi: 10.1016/j.entcom.2016.09.002
- Papert, S. (1991): Situating constructionism. In: I. Harel and S. Papert (Eds.), *Constructionism: Research reports and essays*. (pp. 1–11).
- Quintana-Ordorika, A., Garay-Ruiz, U., and Portillo-Berasaluze, J. (2024). A systematic review of the literature on maker education and teacher training. *Educ. Sci.* 14:1310. doi: 10.3390/educsci14121310
- Romeike, R. 2011 *Logos Erben: Konstruktionistische Ansätze für Mathematikunterricht und Mathematiklehrausbildung*. Available online at: <https://eldorado.tu-dortmund.de/bitstream/2003/32231/1/171.pdf> (Accessed July 15, 2025).
- Sheridan, K., Halverson, E. R., Litts, B., Brahm, L., Jacobs-Priebe, L., and Owens, T. (2014). Learning in the making: a comparative case study of three makerspaces. *Harv. Educ. Rev.* 84, 505–531. doi: 10.17763/haer.84.4.brr34733723j648
- Soomro, S. A., Casakin, H., Nanjappan, V., and Georgiev, G. V. (2023). Makerspaces fostering creativity: a systematic literature review. *J. Sci. Educ. Technol.* 32, 530–548. doi: 10.1007/s10956-023-10041-4
- Stiller, J., Anders, P., Demi, A.-L., Eilerts, K., Grave-Gierlinger, F., and Pech, D. (2023). “Making in der Primarstufe und ihrer Didaktik – Deutsch, Mathematik und Sachunterricht in einer von Digitalität geprägten Welt” in *Jahrbuch Grundschulforschung: Vol. 27. Nachhaltige Bildung in der Grundschule*. eds. M. Haider, R. Böhme, S. Gebauer, C. Gößinger, M. Munser-Kiefer and A. Rank (Bad Heilbrunn: Verlag Julius Klinkhardt), 209–213.
- Stilz, M., Ebner, M., and Schön, S. (2020). “Maker Education – Grundlagen der werkstattorientierten digitalen Bildung in der Schule und Professionalisierung der Lehrkräfte” in *Beiträge zur Lehrerbildung und Bildungsforschung: Band 5. Digital?! Perspektiven der Digitalisierung für den Lehrerberuf und die Lehrerbildung*. eds. M. Rothland and S. Herrlinger (Münster; New York: Waxmann), 143–159.
- Taylor, B. (2016). Evaluating the benefit of the maker movement in K-12 STEM education. *Electron. Int. J. Educ. Arts Sci. (EIJEAS)*, 2:72.
- Unterfrauner, E., Voigt, C., and Hofer, M. (2021). The effect of maker and entrepreneurial education on self-efficacy and creativity. *Entrep. Educ.* 4, 403–424. doi: 10.1007/s41959-021-00060-w
- Wang, Y., Li, Y., and Cai, H. (2025). Integrating maker education into primary science: a case study of the “ship research” curriculum with 3D printing and sensor technology. *World J. Educ. Res.* 12:p25. doi: 10.22158/wjer.v12n3p25