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From Physical Computing to Physical AI: Challenges in Teaching Robotics and AI in Creative Contexts

Ivan Iovine

Chunk 1

Introduction

The integration of AI and robotics into arts education offers significant opportunities, but also presents substantial pedagogical challenges. Given the range of technical disciplines involved, developing and teaching a complete technical pipeline can be overwhelming for students without a technical background.

Chunk 2 Teaching these technologies in an art and design context requires careful structuring to ensure accessibility, clarity, and creative applicability.

II. p. 30, Chunk 6: Offenbach
II. p. 30, Chunk 10: Offenbach
II. p. 160, Chunk 21: Integrating Physical AI and…

Chunk 3 At the Robotics Lab of the University of Art and Design Offenbach am Main, both infrastructural and educational strategies have been implemented to meet these demands. On the infrastructural side, the lab was equipped with digital manufacturing tools and robotic systems, providing students with the technical resources needed to explore and experiment artistically. On the educational side, the program began with a discipline already familiar and well-established in creative coding: physical computing. This initial phase offered a foundational technical context that felt accessible to students from artistic backgrounds. Over the following semesters, the curriculum gradually shifted focus toward more advanced AI and computer vision technologies, ultimately reaching the domain of Physical AI. This emerging field combines AI-based computational systems with physical hardware and robotics, offering new possibilities for the creation of interactive and reactive artistic works.

This article outlines the step-by-step development of both the educational methodology and the supporting infrastructure. It shows how foundational practices in physical computing evolved into more complex learning pathways, and how access to digital manufacturing facilities supported students in integrating these technologies into their artistic processes.

Challenges in Teaching Robotics and AI in Creative Contexts

Teaching robotics and artificial intelligence in a creative context goes beyond providing access to new tools and learning to code. It requires rethinking teaching methods, developing suitable infrastructure, and aligning learning objectives with the diverse needs of creative students.

II. p. 3, Chunk 1: Vorwort
II. p. 21, Chunk 2: Schwäbisch Gmünd
II. p. 180, Chunk 5: Editorial

Chunk 4 Over the past three years, the aim has been not only to transfer technical knowledge, but also to foster confidence, curiosity, and an artistic culture around emerging technologies. Achieving this in a way that is both pedagogically sustainable and artistically open-ended requires careful planning and continuous adaptation. Within this context, several challenges emerged during the implementation of the program at the Robotics Lab of the University of Art and Design Offenbach am Main. The most significant ones were the following:

- *Laboratory Infrastructure:* A significant initial challenge involved establishing a dedicated lab. This lab needed to support the practical teaching of AI, robotics, and physical computing. Additionally, students needed to aquire manual competencies to create physical artifacts integrating these technologies. This included working with digital manufacturing tools such as 3D printers and laser cutters (Figure 2).
- *Cultural and Critical Integration:* Another challenge was developing a culture of robotic and interactive arts. This cultural framework needed to be both technically informed and critically aware. It required showcasing significant existing works in the field. This exposure would

inspire students to develop new artistic works informed by these examples.

- *Technical Overload Prevention:*

It was also critical to avoid overwhelming art and design students new to programming with overly technical instruction. Courses needed a structured, gradual approach, beginning with familiar established technologies. Only subsequently would the complexity increase, integrating robotics and AI technologies progressively.

Chunk 5 Framework and Educational Methodology

The initial teaching framework was based on a Physical Computing course that focused on Arduino microcontrollers. This technology had already been well-integrated at the university before the Robotics Lab was established.

Chunk 6 Building on this familiar technical groundwork, the goal was to offer an accessible entry point into the field of robotics. To support this aim, and in recognition of the need for a more structured progression, targeted refinements were introduced over the first three semesters. A key development was structuring the program as two sequential courses: a foundational course in the winter semesters and an advanced course in the summer semesters. In the foundational courses, students learned essential skills with Arduino, sensors, and actuators. The pedagogical approach followed constructivist principles, which emphasize learning through active engagement, iterative making, and direct manipulation of materials and tools. Rather than delivering abstract knowledge, this pedagogy encourages students to construct understanding by exploring, testing, and building in context.[1] Such approaches have become increasingly popular in the teaching of creative coding, particularly in design and arts education.[2] Students built their understanding through direct interaction with technology and practical, creative applications. To better prepare students for AI topics in the subsequent advanced course, the final four sessions gently introduced computer vision concepts. Students received ready-to-use Python scripts that connected Arduino with computer vision libraries such as OpenCV and MediaPipe. The code was introduced in a simple and approachable way to support those with limited programming experience.

II. p. 155, Chunk 4: Integrating Physical AI and…
I. p. 101, Chunk 10: Bildgenerierende Modelle in…
III. p. 33, Chunk 9: Building AI Intuition – Four…

Chunk 7 Students could explore the scripts by changing values, for example adjusting facial or hand detection settings, and observe the effects. Alongside coding, they applied their hands-on skills to embed sensors and actuators into physical objects.

Chunk 8 They also learned basic digital fabrication methods, including 3D printing and laser cutting. As a result, their skills expanded beyond

1: Hannafin, M. J. (1995). Open-ended learning environments: Foundations, assumptions, and implications for automated design. In R. D. Tennyson & A. E. Barron (Eds.), *Automating Instructional Design: Computer-Based Development and Delivery Tools* (pp. 101–129). Springer Berlin Heidelberg. <https://doi.org/10.1007/978-3-642-57821-2_5>

2: Grace, K., Klaassens, B., Bray, L., & Elton-Pym, A. (2022). An open-ended blended approach to teaching interaction designers to code. *Frontiers in Computer Science*, *4*, 813889. <https://doi.org/10.3389/fcomp.2022.813889>

programming, giving them practical experience in fabrication and material-based experimentation.[3]

Chunk 9 The advanced course expanded upon these initial foundations by incorporating more complex technologies. Students experimented with Raspberry Pi 5 devices and the MediaPipe framework, developing optimized computer vision models for real-time, on-device applications (Figure 2). Unlike the foundational course, this module emphasized practical software development in Python, gradually shifting focus slightly away from physical computing.

Chunk 10 The advanced course aimed to introduce students to Physical AI pipelines with embedded machine learning models that control physical components such as sensors, actuators, and robotic systems.[4]

II. p. 156, Chunk 5: Integrating Physical AI and…
II. p. 159, Chunk 15: Integrating Physical AI and…
II. p. 157, Chunk 9: Integrating Physical AI and…

Chunk 11 This approach aligned with emerging practices in design and interaction, where AI have been used as a materially embodied agent capable of generating responsive, situated experiences.[5]

For teaching and implementing an AI-based robotic pipeline, MediaPipe was selected due to its ease of use and minimal coding abstraction.[6] With only a few lines of code, students could implement computer vision models for face tracking, body tracking, and hand pose recognition.[7] Additionally, the MediaPipe Model Maker offers a straightforward approach for creating custom models. According to the developers, as few as 100 images per class are sufficient to fine-tune a pre-trained MediaPipe model.[8] For educational purposes, students created datasets consisting of approximately 600 to 800 images (with around 200 images per trained class), allowing them to fine-tune existing models to recognize specific gestures, facial expressions, or body movements. This enabled the development of customized interactive artistic experiences.

Chunk 12 After introductory sessions covering Python programming, serial communication, and MediaPipe, students further expanded their knowledge through a constructivist approach. By independently developing their own artistic projects, students actively built deeper coding skills and a practical understanding of the computer vision library. Furthermore, the advanced course introduced industrial robotics technology with a UR10e robotic arm, a cobot designed for safe human-machine collaboration (Figure 1). Students learned to program the robotic arm both via its intuitive teach pendant interface and through Python-based coding. This exploration aimed to inspire students, demonstrating advanced applications in media art and complex performance art projects.

3: Iovine, I. (2023). Integrating artificial intelligence and robotics into art curriculum. In *INFORMATIK 2023 - designing futures: Zukünfte gestalten* (pp. 347–352). Gesellschaft für Informatik e.V. <https://doi.org/10.18420/inf2023_32>

4: Miriyev, A., & Kovač, M. (2020). Skills for physical artificial intelligence. *Nature Machine Intelligence*, *2*(11), 658–660. <https://doi.org/10.1038/s42256-020-00258-y>

5: Coelho, M., & Labrune, J.-B. (2024). Large language objects: The design of physical ai and generative experiences. *Interactions*, *31*(4), 43–48. <https://doi.org/10.1145/3672534>

6: Iovine, I. (2024). Robotik und computer vision im künstlerischen Kontext. *Un/learn AI*. <https://unlearn.gestaltung.ai/article/dizhepje>

7: Lugaresi, C., Tang, J., Nash, H., McClanahan, C., Uboweja, E., Hays, M., Zhang, F., Chang, C.-L., Yong, M. G., Lee, J., Chang, W.-T., Hua, W., Georg, M., & Grundmann, M. (2019). *Mediapipe: A framework for building perception pipelines*. arXiv. <https://doi.org/10.48550/ARXIV.1906.08172>

8: Google. (n.d.). *Mediapipe model maker | google AI edge*. <https://ai.google.dev/edge/mediapipe/solutions/model_maker>.

II. p. 158, Chunk 10: Integrating Physical AI and…
II. p. 156, Chunk 6: Integrating Physical AI and…
I. p. 88, Chunk 14: Robotik und Computer Vision…

Chunk 13

Figure 1: Students testing a custom hand pose model on a UR10e robotic arm, with each gesture triggering a predefined movement. © Ivan Iovine

Outcomes and Lessons Learned

The implementation of a sequential two-semester course structure significantly enhances student engagement and learning outcomes.

Chunk 14 Dividing the curriculum into a foundational course in the winter semester and an advanced course in the summer semester proved essential. This format provided students with a clear and accessible entry point into physical computing, followed by a gradual introduction to more complex AI and robotics technologies such as Raspberry Pi 5 and MediaPipe.

Chunk 15 Computer vision, as an established technology, proved to be a particularly effective choice. Unlike other AI-based technologies, especially those involving generative models, it has not been subject to rapid architectural changes or disruptive codebase shifts.

Chunk 16 This technical stability has allowed for reliable instruction as well as tutorials, consistent learning outcomes, and a smoother integration into the overall teaching framework.

A fully equipped robotics lab was established to support this learning pathway. The lab was composed of two complementary sections: a seminar room for theoretical instruction and a digital manufacturing area equipped with tools such as 3D printers and a laser cutter (Figure 2). This setup enabled students to move seamlessly between conceptual learning and hands-on experimentation.

Chunk 17 They gained not only technical knowledge in AI and robotics, but also practical skills in creating physical artifacts that integrated these technologies (Figure 3).

Figure 2: Robotics Lab at University of Art and Design Offenbach am Main. © Ivan Iovine

II. p. 158, Chunk 13: Integrating Physical AI and…
II. p. 157, Chunk 8: Integrating Physical AI and…
I. p. 65, Chunk 10: AI+D Lab (HfG Schwäbisch Gmünd)

Chunk 18

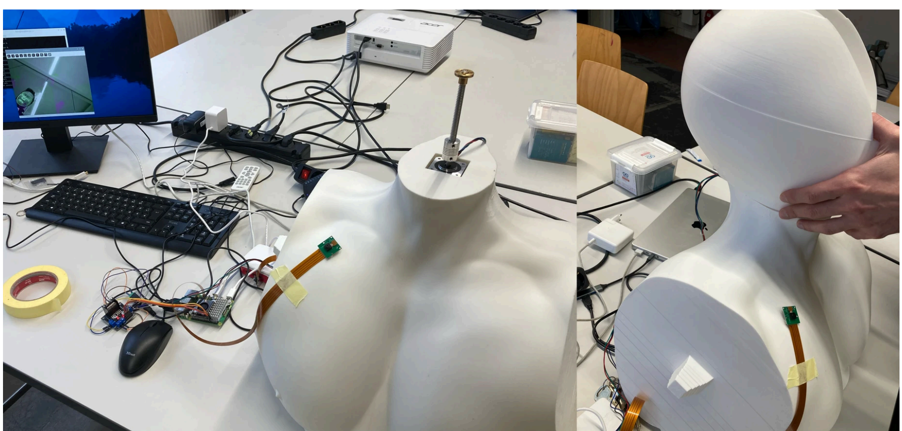

Figure 3: Prototype installation experimenting with a stack combining Physical AI and digital fabrication techniques. © Ivan Iovine

From the outset, the course also aimed to foster a critical and artistic understanding of robotic and interactive art. Students were introduced to exemplary works and DIY projects in the early sessions, which served as inspiration for their own artistic exploration. This emphasis on conceptual framing and reference works, combined with a constructivist teaching approach, encouraged students to actively build knowledge by engaging creatively with both the technical and artistic aspects of the field. This pedagogical strategy helped to prevent the risk of technical overload, especially for students with little or no programming experience. By beginning with accessible tools like Arduino and gradually increasing technical complexity, students remained engaged without feeling overwhelmed. The progression allowed them to develop confidence and competence step by step.

II. p. 158, Chunk 11: Integrating Physical AI and…
II. p. 157, Chunk 8: Integrating Physical AI and…
II. p. 156, Chunk 5: Integrating Physical AI and…

Chunk 19 The results of this structured approach were evident in the students' final projects. Those who participated in both semesters demonstrated notable improvements in technical proficiency and creative expression. Many projects successfully implemented a Physical AI pipeline by combining computer vision with physical computing components. As depicted in Figure 4, examples included interactive sculptures using real-time vision to control servo mechanisms, as well as robotic installations operated by custom-trained machine learning models running locally on Raspberry Pi 5 devices.[9] As illustrated in Figures 5 and 6, experienced students also integrated industrial robotic arms into their work, especially in media and performative arts.[10] Through independent project work and guided exploration, students developed technical skills, autonomy, and the ability to design and implement original, technologically advanced artworks.

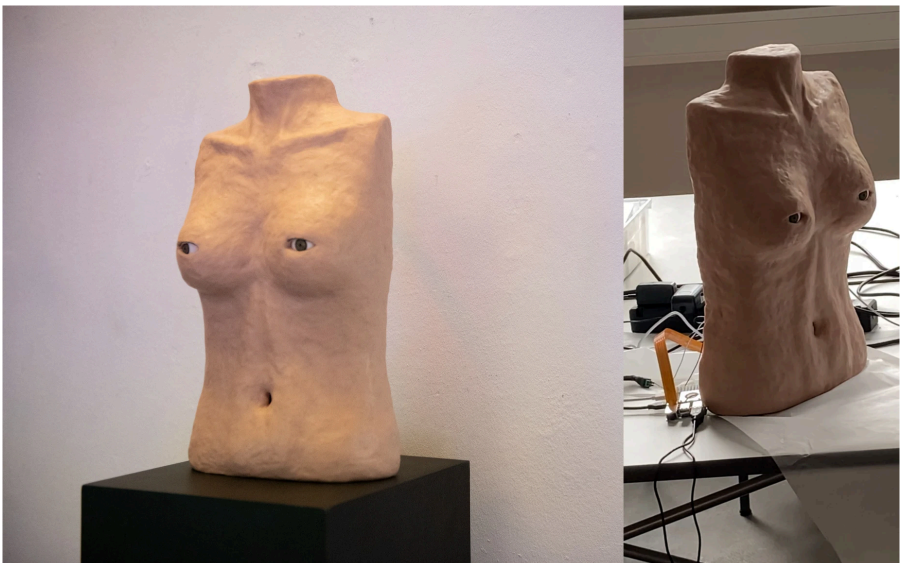

Figure 4: The interactive sculpture *Stalking* by Soyeon Park, which employs a Physical AI pipeline, exhibited at the Correlations 2024 conference as part of the KITeGG research project. © Cheesoo Park, Ivan Iovine

9: Iovine, I. (2024). Robotik und computer vision im künstlerischen Kontext. *Un/learn AI*. <https://unlearn.gestaltung.ai/article/dizhepje>

10: Iovine, I. (2024). Robotik und computer vision im künstlerischen Kontext. *Un/learn AI*. <https://unlearn.gestaltung.ai/article/dizhepje>

Chunk 20

Figure 5: The media art installation *Door Bitch* by Rahel Pabst, exhibited during the annual Rundgang and the Correlations 2024 conference as part of the KITeGG research project. © Rahel Pabst, Cheesoo Park.

I. p. 111, Chunk 18: Creating easy to use interfaces…
II. p. 245, Chunk 34: Der KITeGG Cluster – eine…
I. p. 10, Chunk 7: Projektvorstellung

Chunk 21

Figure 6: The performative installation *Schlag auf Schlag* by Nelli Gomez Baumert, exhibited during the Correlations 2024 conference as part of the KITeGG research project. © Cheesoo Park.

Chunk 22

Conclusion

Integrating AI, computer vision, and robotics into art and design curriculum involves rethinking both teaching structures and learning environments. The experience at the Robotics Lab of the University of Art and Design Offenbach am Main shows that it is possible to introduce complex technologies into creative contexts without compromising accessibility or artistic exploration. By beginning with physical computing and gradually expanding to advanced AI tools, students are able to engage with these technologies at a sustainable pace.

Chunk 23 The two-semester structure, combined with a constructivist teaching approach and dedicated infrastructure, provides a solid foundation for experimentation, technical growth, and artistic development. Throughout the program, students not only acquire new technical skills, but also develop a critical and cultural understanding of the role of intelligent systems in contemporary artistic practice.

Chunk 24 Their final projects demonstrate how emerging technologies can be meaningfully integrated into creative workflows, producing original and context-aware artworks. These outcomes underscore that, with thoughtful pedagogical design, robotics and AI can become integral components of creative education.

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