GENERAL ARTICLE

Linking Science and Technology with Arts and the Next Generation

The STEAM Imaging Experimental Artist Residency, A Case Study

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ABSTRACT

The author describes designing an artist-in-residence project within a research institute for applied science as a dialogue-oriented form of science communication and education. The author collaborated with a scientist, an artist, a software architect and a sound designer to realize the STEAM Imaging pilot project as a conceptual framework for fostering collaborative engagement among school students, scientists and an artist. A constant through the project is the connection of tools for computer-assisted medicine with teaching topics from science, technology, engineering and mathematics (STEM). The first artist in residence, Yen Tzu Chang, integrated programming for sound art, creation of plaster models and discussion on ethical topics. The aim was to foster engagement with and ownership of future technology.

WHY STEAM IMAGING?

As Head of Communications focusing on science communication at Fraunhofer MEVIS, I mediate the procedures developed to transform digital, integrated precision medicine through systematic computer support as well as the required contributions of mathematics, physics and computer science. The Institute's research aims to enhance decision support and information integration for physicians, supporting them in recognizing severe diseases such as cancer more reliably, tailoring treatments to each patient and making therapeutic success measurable. Applied research in medical technology is affected in many ways by increasingly shorter innovation cycles. The rise of digitalization, big data, artificial intelligence and biotechnology demands a prompt discussion of social implications. Big data and artificial intelligence, in particular, sharpened the shift in science toward economic output—the focus has changed from the fundamental understanding of basic principles of nature to approximations and predictions based on vast amounts of data and statistics. This change in focus influences ideas about our future and precipitates rethinking the pure economization of science and knowledge to observe the societal and ecological effects of science and technology. Computer scientists are challenged to integrate other disciplines, such as ethics, psychology, sociology and art.

Fig. 1. The residency's key visual, the STEAM-brain. A fusion of anatomical and functional MR imaging shows the brain areas that are activated while a person listens to music, although the steam comes from a locomotive. (© Fraunhofer MEVIS)

I create formats that let experts remain in their fields of expertise and that involve the public at an early stage, such as the STEAM Imaging residency (Fig. 1). This helps engender discussion among scientists about their work to gain clarity, sense and composure concerning their R&D. I have led various projects disseminating and communicating, hence demonstrating, the value of the Institute's R&D [1], inspiring nonexperts to engage in sci-tech topics, for instance, through interactive hands-on exhibits. Starting from the interactive moving images of the exhibits, especially the 4D moving images of the heart integrated into the interactive exhibit *Image Man* [2], I further developed with my colleague Alexander Köhn a craft of visual storytelling. We started to produce short films in 2D, 3D [3] and immersive experiences in 360° [4] by processing moving images based on real medical data to provide wider receptions for the audience. I focus on aesthetics to remove barriers that prevent interaction with severe health topics, thereby creating an approach to STEM

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that provides joy, amazement and fun. With these movies and exhibits, we generated a massive outreach effort with hundreds of thousands of visitors and reached target groups not familiar with STEM. Hands-on workshops with the young generations are another format of sci-com at the Institute. We offer a wide range of courses led by scientists such as mathematician Sabrina Haase. These professionals place an abundance of trust in school students, connect them with the research activities at the Institute and impart concrete knowledge so that they can participate actively. The scientists make the role and importance of STEM subjects for medicine tangible and offer role models for girls. In return, the scientists explain their fields of work to nonexperts and thus reflect on their discourse with school students in a different way than with their colleagues.

PERFORMING A-I-R AT FRAUNHOFER MEVIS

I started exploring how a tech-oriented institution could integrate the arts in our sci-com to foster socially responsible technology engagement and lead informed public discussion and decision-making. Existing artist-in-residence (a-i-r) programs included outlined institutionalized plans far removed from the everyday realities of an industry-oriented research institution. I needed a bottom-up approach in which researchers and developers served as a driving force. I found allies for whom such a project would offer new opportunities and value, from enhancing their own workshop experience to having a chance to participate playfully in the Institute's sci-tech, following paths of curiosity or pushing the boundaries of its usage. Together with my colleagues, I designed a concept and defined the goals of the residency and the roles and responsibilities within the new team. I focused on the Institute's technology, such as our 3-tesla MRI scanner and MeVisLab, a rapid-prototype software development platform that allows processing of medical data and building assistance tools for clinicians [5]. I integrated the Institute's values and culture, namely the interdisciplinary orientation governed by transparency and cooperation. The employees act in a flexible network and are not bound to a hierarchy. Sharing information is encouraged and expected at all levels, and the STEAM team is actively aided by using a collaborative social platform. In addition, I integrated established and successful STEM courses for young researchers, with which Fraunhofer MEVIS already has a lot of experience, although this is not the Institute's primary mission. During these events, the scientists teach dedicated STEM topics, nurture talents, promote and support intrinsic motivations, and practice scientific thinking. In the field of medical technology, interdisciplinary work is normal, but when I asked my colleague Sabrina Haase whether we could integrate art within a STEM workshop, she was surprised, then enthusiastic, while confessing that she had no idea where it would lead. We received funding from the Fraunhofer Gesellschaft's young talents marketing department.

On behalf of MEVIS, I mediated between the participating scientists and the artist. On the artistic side, we depended on cooperation with experienced partners to find, select and mentor the artists. Subsequently, Fraunhofer MEVIS began a fruitful partnership with Ars Electronica as part of the European Digital Art and Science Network [6]. The artist in residence was Taiwanese media artist Yen Tzu Chang. In the initial phase of the residency, she worked closely with scientists at the Institute for two weeks. The scientists provided expertise in topics such as auditory guidance in the operating room, segmentation of the heart and machine learning. In the second phase, the artist resided at the Ars Electronica Future Lab for several weeks to finish her artwork, a performance installation titled *Whose Scalpel*, which addresses the future of the relationship between humans and machines in surgery. The team hosted an open discussion on ethical issues with coworkers. Yen Tzu Chang has experience in developing electronic instruments inspired by the methods and approaches of both natural and computer science. Within the residency, she aimed to expand her artistic toolbox. To develop her artwork, she acquired an MRI scan of her body (Fig. 2) and started to learn MeVisLab. The artistic outcome, titled *Whose Scalpel* [7] (Fig. 3), is a fusion of an interactive 3D model of the artist's heart and movies based on her medical images. It invites the question: If machines can reason even better than humans, will we lose some of our abilities and even stop believing in ourselves? The artwork's concept is based on the application of sound in medical technology, coronary artery bypass surgery and machine learning. The underlying story is based on the idea that, in the future, machines will give advice to surgeons. Chang states that sound

Fig. 2. Artist Yen Tzu Chang is scanned at the Institute's MRI scanner to acquire medical data for the blood flow visualizations and 3D model of her heart. (© Fraunhofer MEVIS)

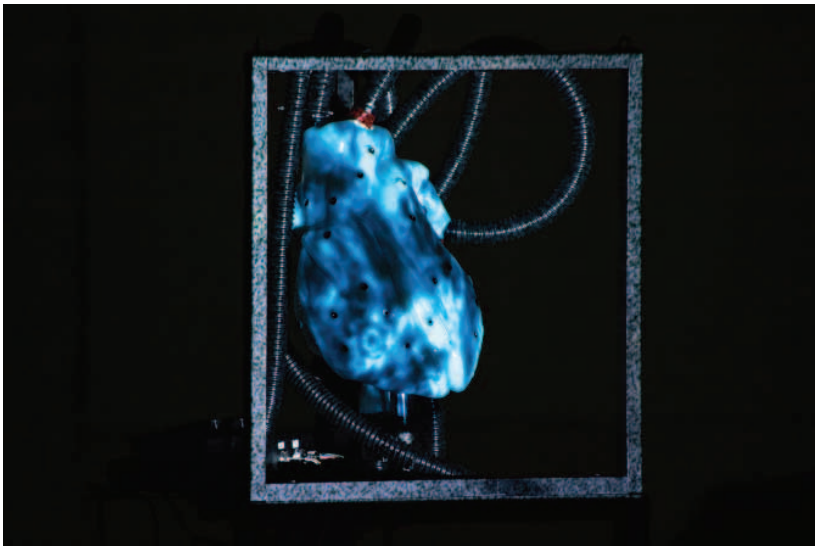

Fig. 3. Yen Tzu Chang's installation performance *Whose Scalpel* is based on a 3D-printed model of the artist's heart equipped with lights and electronic sound generators. (© Fraunhofer ICT Group)

in the performance not only serves to provide an atmosphere but has been essential in diagnoses such as stethoscope examinations. Auditory guidance systems for navigated liver surgery inspired her to apply the concept of *Whose Scalpel* to this residency program [8]. Chang transformed her heart, supersized and 3D-printed, into a musical instrument (Fig. 4). The enlarged model of her heart is designed for interaction by plugging in audio cables to bridge connections. Chang equipped the inner parts with electronic components such as an Arduino system and LEDs. Coronary bypass surgery enables blood to follow a new path, which Chang describes as an approach similar to a modular synthesizer, which routes a signal from one module to another to produce sound. During the performance, the artist plugs in the cables and triggers sound. The artistically imagined AI is a character in the performance who speaks offstage. The AI is in charge of critical medical tasks and gives suggestions and advice to the performing artist-surgeon. The surgeon's goal is to cure the heart, which symbolizes human faith and consciousness. However, no machine learning technology or deep learning networks are used within the artwork. In addition to MeVisLab, Chang used Blender and a 3D tool to create the model and Mind Mapper for some videos. Chang used PureData for the multimedia performance and Audacity for sound editing. The performance is neither easy nor catchy for visitors, but it features a conciliatory finale in which the heartbeat of the heart model on which the surgery is performed matches that of the surgeon.

In public forums, the idea of an AI as an intelligent entity taking over the role of doctors is stressed, but in the clinical reality, the process of collaboration between computers and doctors has been already rewritten. Workflows in diagnoses, therapy planning and therapies are changing, and disciplines, human-computer interaction and decision-making are merging. When does a surgery begin: At the moment the surgeon applies the scalpel? When the intervention is planned? When an operation on a specific patient is simulated in advance? Such procedures are already the reality. In particular, tedious tasks such as automated laboratory and image analysis will be more often performed by the computer, which will present the analyzed results to the clinicians for diagnosis. Predecisions are being made without the clinicians. In addition, machine

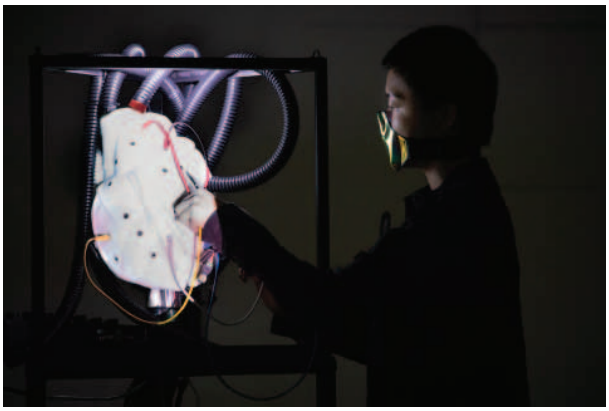

Fig. 4. Yen Tzu Chang performs *Whose Scalpel* at the Fraunhofer Society's event The Art of Complexity in Berlin, 5 June 2018. During the performance, Chang acts as a "surgeon" and places a bypass with the help of cables. (© Fraunhofer ICT Group)

Fig. 5. Students work at the STEAM workshop under the guidance of mathematician Sabrina Haase. (© Martin Hieslmair/Ars Electronica)

learning (concrete deep learning convolutional neural networks) is already capable, for instance, of outperforming extensively trained dermatologists in detecting melanomas [9].

THE SCHOOL STUDENTS' STEAM WORKSHOP

A key element of the artist's residency was the two-day hands-on workshop [10] with school students that Chang hosted with Haase, an experienced workshop leader (Fig. 5). The roles of teacher and learner, giver and taker changed dynamically between scientists and artist. The STEAM workshop introduced the school students—22 girls and 20 boys in grades 7 to 9—to a problem-centered approach to learning. The fusion of theoretical contributions and explorative teaching activities was essential in creating a holistic experience [11]. The courses in Bremen and Linz were somewhat different. In Linz, no MRI scanner was available, although we held a Skype call with the laboratory, and Haase and Chang worked with one large group instead of dividing the crowd. The feedback from the school students in Bremen was also considered when preparing for the workshop in Linz. All students created artistic images and short video sequences combined with ambient noise, sounds of the MRI, or sound recorded and processed with microphones soldered by and sound software programmed by the students. They discussed ethical questions and the impact of new technologies in health care, such as patient data and privacy issues. They held audiovisual performances to showcase their achievements. An external evaluator concluded in her report [12] that the workshop allowed art and STEM subjects to be interleaved. Especially in Bremen, students nevertheless felt a division, which was also visible at the beginning with the class in Linz. However, this ended up blurring borders and creating unexpected outcomes. The exploratory setting of the workshop demonstrated to students that problems and research situations are addressed and answered by combining knowledge from different subjects. Students were also introduced to basic hardware and software technologies and became familiar with how sound and visuals affect human perception to generate meaningful content. In addition to gaining knowledge about anatomy, medical imaging, sound art, plastering and soldering, the young students learned to work with STEAM creatively and with self-empowerment. However, the evaluation did not show whether the workshop reached school students with no prior interest in STEM. We will address this issue in the future through closer cooperation with schools and teachers.

OUTCOME

STEAM Imaging was an experiment in dialogue-oriented sci-com to realize a space for possibilities not predefined. The players and content were selected, but no one knew what the results would look like. What mattered were collaborative exploring, learning in personal encounters, relating to each other and openness to what could emerge. However, there is room for improvement. It was challenging to boost creativity in the office environment to reach beyond working at a computer. It was difficult to open and engage the actors in the process within the daily goal-oriented routine of applied R&D. The team would have enjoyed having more time for face-to-face encounters to allow playfulness, ambiguity and collaboration within the transdisciplinary process. We believe this could have increased serendipitous benefits. STEAM Imaging was an exploration of a future transdisciplinary educational model to strengthen the bond between R&D and the coming generation's engagement with upcoming technology. Applied research organizations can host such intergenerational projects to confront the impact of technologies at an early stage. If society truly aims to foster the talents and resources of every child, the cooperation of different social actors (not only teachers) is necessary within flexible permanent learning environments. In Germany, a child's education level still largely reflects that of their parents. It is essential to expand research teams, not only using art, ethics and sociology, but to include, for example, women and people of color.

STEAM Imaging served as an incubator for all participants to act without being measured. It allowed participants to learn specific knowledge and to deal creatively with medical imaging. At the same time, students were granted space to work autonomously. The influence of role models for young people cannot be stressed enough. The aim of such project-oriented learning is not to impart a canon of knowledge but to allow students to conduct an exemplary and deep examination of a topic and learn how to autonomously develop new topics and handle real-world technologies. The working methods at Fraunhofer MEVIS range from planned and structured to iterative and creative. The approach partially resembles the artist's methods, although the spectrum covered by her solutions was much broader. This dialogue-oriented sci-com project allows scientists to contextualize their expertise and to create a mutual process: The scientists learn to relate their developments to social realities and ideas, opinions and values of other actors and to reflect more upon their actions than is often possible during everyday work. These relations challenge the researchers at a personal level because they

cannot refer to or rely on defined procedures and processes. They also expose themselves to questions that they may not be able to answer. An example of this is the ethical discussion that took place within the framework of the residency. The scientists pondered their responsibilities as individuals and as part of an organization in technological development. How do they behave and position themselves as employees and as an organization? There are informal ethical discussions of issues relevant to our topics, but the artist's questions and artwork provided a point of crystallization to come together in a group and reflect upon the possibilities, side effects and risks of the Institute's R&D [13].

A fundamental understanding of technology must always be a part of education. However, because of the rate of development, this can no longer be achieved solely by the working generation. Intergenerational dialogue, especially in education, is needed. Today, the ability to learn, change, adapt and be flexible and open to new skills and knowledge are crucial for employees, companies and organizations. As innovation cycles in R&D become shorter and more complex, the ability to move fluidly between disciplines is an essential competence. In the current educational system, test- and goal-oriented development of knowledge has limited the discovery, support and, most significantly, expression of talent. Students focus on external goals instead of experiences and growth of their abilities. The revolution in communication technology in the last decade has proven to be a social revolution and has contributed to this shift. Self-restricted thinking, depending on the judgment of others, leads to limited innovation. Pilot projects such as STEAM Imaging experimentally explore how spaces, both physical and metaphorical, could be conceived and established. Such new formats locate experts in their field of expertise, pave the artists' ways toward new technologies, open further professional areas and, in the case of STEAM Imaging, include teaching school students. The STEAM Imaging residency and students' workshops were hands-on experiences to help exit the trodden paths of teaching and learning STEM. It was an experiment in letting knowledge flow between generations. The residency served as an equalizer. The strategies of the artist influenced the researchers' usual approaches and allowed them to develop and conduct a collaborative STEAM workshop.

Yen Tzu Chang remarked that STEAM projects like this one are an excellent opportunity for young people to become acquainted with art and assess its significance. This, her first STEAM workshop, increased her understanding of how to lead a group and what school students require in such seminars. This sparked her development of further approaches to mediating educational encounters with technology and art. She has continued working on projects in a social services agency to help establish hands-on workshops and create interactive devices for children and teenagers [14]. Additional results inspired by the residency include the scientists' awareness of existing intersections with the arts. This inspired the creation of medical image video performances with school students, not only as a gimmick but as a result in its own right, as well as the "Inside Insight" Web app. The software used in the students' workshops, a light version of the MeVisLab platform, has been developed over the years and transferred into a Web application by software developer Alexander Köhn. The team integrated the training materials with artist Hannah Klatt and augmented them with an explanatory voiceover. Using Inside Insight, Sabrina Haase is now combining science and art in an online workshop to teach medical image processing methods.

STEAM workshops could be part of scientific project dissemination strategies. With this project, I encourage other industry-related institutions and companies to implement suitable formats of artists' residencies. These should be tailored to their technologies and expertise, values and culture. Such formats should ease making contact with other societal actors. This could impact promotion of young talent (such as in STEAM Imaging). Companies must envision our next generation no longer as solely consumers but also as future citizens and employees. The impact can also manifest itself in innovative processes, such as those targeted in the STARTS calls [15] or in the development of human resources to improve managers' sensitivity for societal trends. Sound STEM education is indispensable for becoming engaged with, creating and owning societally beneficial technologies. Involving artists in STEM education and development of technologies not only poses further questions for researchers and enhances aesthetic dimensions and design but encourages all participants to engage creatively with STEM knowledge in a process of a transdisciplinary invention.

Acknowledgments

I thank the curious and courageous colleagues from Fraunhofer MEVIS R&D—doers, makers, contributors—who made these explorations and projects possible. Many thanks to David Black and Viktoriya Viktorova for editing my English manuscript.

References and Notes

1 See examples: www.mevis.fraunhofer.de/en/press-and-scicom/science-communication.html.

2 *Image Man* interactively showcases the capabilities of modern medical imaging methods. At the center of the installation is a touch screen showing a beating heart. By touching, visitors can interactively navigate through the results of different imaging methods. A 3D-CT image serves as a spatial illustration of the heart. A sequence of blood-flow MRI reveals the blood streaming through the vessels and swirling turbulently. See a video of the *Image Man* moving heart: https://youtu.be/n4kIqNFsEEw. See the 3 June 2015 press release: www.mevis.fraunhofer.de/en/press-and-scicom/press-release/an-_image-man_-you-can-touch.html.

3 Encouraged by experiences with Yen Tzu Chang, we cooperated with artists Ina Conradi and Mark Chavez to create a short movie titled *Digital Medicine, Arts, and STEAM: BEFORE US LIES ETERNERDY*, which won the Industry Award for Best Infographic at the Raw Science Film Festival, 2019, in California, U.S.A. It offers an artistic,

large-scale immersive experience and was produced in 2D for the 15-×-2-m Media Art Nexus video wall at NTU, Singapore and in stereoscopic 3D for the Deep Space 8K, Linz, Austria. It premiered in September 2018 at the Ars Electronica Festival. See a 16:9 2D preview video with a voice-over of the stereoscopic 3D version: https://youtu.be/oMJdszJ8PxQ.

4 For the short movie *Beauty of Blood Flow Analysis*, we received the Industry Award for Best Immersive Media at the 4th Raw Science Film Festival: The Bridge between Science and Media, held in January 2018 in Santa Barbara, CA, U.S.A. It was nominated at the 12th FullDome Festival in Jena, Germany, May 2018. See a blog post and a 2D preview of the 360° video at www.rawscience.tv/the-beauty-of-blood-flow-analysis.

5 MeVisLab home page: www.mevislab.de.

6 Ars Electronica Center Linz, *The Practice of Art & Science: The European Digital Art and Science Network* (Hatje Cantz, 2017) pp. 50–55.

7 Y.T. Chang, sound sculpture, master thesis on stage, 2017, Linz. Chang presented *Whose Scalpel* for the first time at the Ars Electronica Festival in Linz, Austria, in September 2017, and additionally in April, June and August 2018 in Munich, Berlin and London, respectively.

8 C. Hansen et al., "Auditory Support for Resection Guidance in Navigated Liver Surgery," *International Journal of Medical Robotics and Computer Assisted Surgery* **9**, No. 1, 36–43 (March 2013). See video: www.youtube.com/watch?v=gCg5nJSI2pY.

9 H.A. Haenssle, "Man against Machine: Diagnostic Performance of a Deep Learning Convolutional Neural Network for Dermoscopic Melanoma Recognition in Comparison to 58 Dermatologists," *Annals of Oncology* **29**, No. 8, 1836–1842 (August 2018).

10 Find more details in B. Hofmann, S. Haase, D. Black, "STEAM Imaging: A Pupils' Workshop Experiment in Computer Science, Physics, and Sound Art," *SciArt Magazine* **26**, Special Topics: STEAM (August 2017): www.sciartmagazine.com/steam-imaging-a-pupils-rsquo-workshop-experiment-in-computer-science-physics-and-sound-art.html (accessed 2 April 2018).

11 For the Evaluation Summary, see C. Schnugg, "STEAM Imaging: Art Meets Medical Research: Evaluation Summary" (2017): www.researchgate.net/publication/318572754_STEAM_Imaging_Art_Meets_Medical_Research_Evaluation_Summary.

12 C. Schnugg, "Art Meets Medical Research, Evaluation" (2017), unpublished manuscript, accessible upon request.

13 We achieved funding (by the Federal Ministry of Education and Research) for a research project jointly with ethicists, ELSA–AID: www.gesundheitsforschung-bmbf.de/de/elsa-aid-kunstliche-intelligenz-in-der-diagnostik-ethische-berufliche-und-soziale-aspekte-11030.php.

14 Y.T. Chang, email communication with the author (25 February 2018).

15 European Commission, "ICT and Art—the STARTS Initiative": www.ec.europa.eu/digital-single-market/en/ict-art-starts-platform.

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