Experiential Learning and BioFabLab

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Abstract: This article describes Roskilde University BioFabLab's practice of experiential learning in which STEM topics are integrated with the FabLab movement's democratization of technology. Inspired by sandbox approaches from technology development, priority is given to curiosity and the learner's interest. BioFabLab enables students to pursue their own interests while learning more about Biology, Chemistry, and Biotechnology. Two examples illustrate how the students prototype their way to learning, as they create biostone from sand and urea or transform household waste into chicken feed through biological fabrication.

Introduction

The need for interest in science

In science education research, there is a strong focus on maintaining students' interest in science. This is because many children or young people's interest in science decreases as they move through the education system. Science programs face two major challenges: maintaining interest in science among pupils at primary and secondary school levels and retaining students who have begun a science program at university.

Studies show that European youths often experience science as irrelevant to their everyday lives (Sjøberg et al., 2006). According to reports from the Danish government in 2016 and 2018, Denmark is one of the countries with the highest dropout rates among students in science programs (Seidelin, 2019, p. 14). This calls for new approaches; it is necessary to develop new ways of learning science (Seidelin, Wahlberg & Holmer, 2018, p.1).

Experiential learning in BioFabLab

This article presents a development project based on student-driven projects in laboratory environments that resemble a kitchen or a greenhouse. The development project introduces perspectives for creative teaching in science.

We describe Roskilde University's BioFabLab and some of the science and technology-oriented teaching activities rooted there, and we frame these activities theoretically as experiential learning. The article argues that experience and learning are two sides of the same coin, demonstrating how teachers and students can engage in experiential learning by working collaboratively with biotechnology in a biological fabrication laboratory.

The article presents BioFabLab's practices as part of the university's study activities. The teaching activities do not provide in-depth instructions in specific biological subjects, such as microbiology, physiology, or enzyme kinetics. Instead, BioFabLab activities are integrated into students' interdisciplinary projects. At the bachelor's level, according to the qualification framework for higher education, the learning objectives include being able to evaluate theoretical and practical issues, justify and choose relevant solutions, handle complex and development-oriented situations, and participate independently in disciplinary and interdisciplinary collaboration. Students should also be able to identify their own learning needs and structure their own learning in various environments.

Method: Pedagogical Development Work

The development project took place from late 2017 to summer 2019. It draws on a cluster of research approaches within the humanities and social sciences that all prioritize practice as a source of knowledge. Common to these approaches is the emphasis on "doing" and exploratory "trying things out" as part of academic knowledge production. The basic idea is that a valuable way of learning and knowing is through practice and reflection upon it (Chapman & Sawchuk, 2012; Leavy, 2009; Koskinen et al., 2011; Schön, 1992). This kind of learning and knowledge production often involves integrating a creative process, an experimental aesthetic component, or artistic work into a project. The pedagogical and didactic research approach, *design-based research* (Christensen et al., 2011), is also part of these practice-oriented methodologies.

One of the article's authors, Martin Malthe Borch, is the initiator and founder of BioFabLab RUC and teaches the reported activities. Martin holds an engineering degree in biotechnology and a master's in interaction design. The other author, Associate Professor Connie Svabo, conducts research in experience design and engages in work at the intersection of experience, aesthetics, and science, for example, as head of the Experience Lab research center at Roskilde University. The collaboration between the two authors stems from a wish to promote experience-oriented approaches to the communication and learning of nature and science.

The article does not present a study positioned outside the field; instead, it conveys a development project in which we are actively embedded. The quality criteria relevant for assessing the research, in our view (inspired by Brinkmann & Tanggaard, 2013, p. 523), are particularly *transparency* and *recognizability*. The empirical basis of the article consists of the teachers' experiences as well as student reports and evaluations. The empirical examples illustrate a theoretical perspective that emphasizes the connection between experience and learning and describe student-driven projects in a scientific and technological laboratory context.

A fundamental assumption of the development work is that the biological fabrication laboratory enables different forms of engagement than the traditional biology laboratory. The didactic development work was carried out in line with the pragmatic philosophy that informs, among others, the FabLab movement's approach to technology. This pragmatism has a simple and emancipatory foundation: to provide all kinds of users access to a technological fabrication environment and equipment, enabling students, artists, entrepreneurs, and other interested individuals to create what they wish (Haldrup et al., 2018). This pragmatic approach stands in contrast to scholastic approaches to learning.

Theory

Not a Scholastic Approach

Scholastic approaches view learning as something that comes "from the outside," where a pupil or student acquires a predetermined body of knowledge. This knowledge can, for example, be found in a curriculum or in the teacher's expertise. The learner is expected to acquire existing knowledge and is regarded as an "empty vessel" to be filled.

> "Learning here means acquisition of what already is incorporated in books and in the heads of the elders. Moreover, that which is taught is thought of as essentially static. It is taught as a finished product, with little regard either to the ways in which it was originally built up or to changes that will surely occur in the future. It is to a large extent the cultural product of societies that assumed the future would be much like the past, and yet it is used as educational food in a society where change is the rule, not the exception." (Dewey, 1938, p. 19).

Dewey – and many others – criticized this approach to learning. It is often replaced by more situated, relational, and dynamic approaches to learning (Dewey, 1938; Vygotsky, 1962; Lave & Wenger, 1991). Nevertheless, it remains relevant to be aware of the scholastic understanding, as many contemporary teaching practices are still oriented toward "knowledge acquisition" and, for example, seek to validate the effectiveness of new teaching methods by isolating specific methods and quantitatively demonstrating their learning effect. This is evident when the use of virtual reality for science education is promoted and tested for its "learning effect" (see e.g. Makransky, Terkildsen & Mayer, 2019).

One place where the dissonance between cognitively acquisition-oriented approaches and pragmatic, situated, and relational approaches becomes clear is in the discourse about informal learning environments such as museums and science centers. Museums are increasingly inviting play and experience into their spaces. At times, however, contributions appear in public debate where someone argues "against superficiality" and "for learning, knowledge, and academic rigor." Experience is thus positioned in opposition to learning, knowledge, and rigor, as if undergoing an experience necessarily comes at the expense of learning. This is a problematic misunderstanding, since it separates two phenomena that are deeply intertwined (Dewey, 1938; Kolb, 1984). When learning and knowledge are regarded as detached from the learner's own experience, the potential for teaching and communication becomes limited. Learning is inseparable from experience.

Learning and Experience Belong Together

Dewey's work provides an important foundation for experiential learning – both philosophically and methodologically. A key point for Dewey is that learning and experience are always connected. This does not mean that all experiences lead to relevant learning, but that experience is always at play in relation to learning. In educational philosophy and learning practice, learning and experiences are linked in the approach known as *experiential learning and education* (Kolb, 1984). As formulated by Smith and Knapp in *Sourcebook of Experiential Education*:

"Experiential education is a philosophy and methodology in which educators purposely engage learners in direct experience and focused reflection in order to increase knowledge, develop skills and clarify values" (Smith & Knapp, 2011, p. 3).

Experiential learning can be found in traditional teaching, alternative education, outdoor adventure education, place-based learning, career learning, therapy, social work, and employee and career development (Smith & Knapp, 2011; Roberts, 2012). It relates to the "human potential movement" of the 1960s, '70s, and '80s and to the "humanistic education movement." Experiential learning forms the foundation for "wilderness learning", outdoor and environmental education, which is particularly common in the US and Canada. It is also related to the "adventure education movement," which includes rope and team challenges, expeditions, rappelling, backpacking, climbing, sailing, environmental awareness activities, and “community service learning” (Smith & Knapp, 2011).

The focus here is on activities that prioritize “direct experience.” It is a diverse field, and there has been extensive discussion about the learning effects of some of these activities. It is relevant to consider the criticism of experiential learning activities. Roberts summarizes this criticism by pointing to a lack of philosophical or theoretical foundation for experiential learning practices. There are many different forms of experiential learning, some of which lack a strong theoretical and philosophical basis. However, according to Roberts, the necessary foundation can be found precisely in Dewey (Roberts, 2012, p. xi).

Dewey: Experience as Interaction Between Individual and Environment

Experience occurs in the interaction between the individual and the environment. Dewey emphasizes that experience occurs both within a person (in the sense that will and purpose are rooted in the individual) and has an active, reciprocal dimension. In this way, experience can be seen as both an individual and a situated, relational, and dynamic phenomenon. Dewey writes:

> “Experience does not go on simply inside a person. It does go on there, for it influences the formation of attitudes of desire and purpose. But this is not the whole of the story. Every genuine experience has an active side which changes in some degree the objective conditions under which experiences are had” (Dewey, 1938, p. 39).

By engaging with experiential learning, it becomes possible to address and draw on both what is happening within the individual learner and what is happening in the environment – that is, existing knowledge in a field, the teacher's priorities, and how the physical surroundings and materials shape the learning situation.

The Environment as an Inspirer of Experiential Learning

The situation, including the physical environment, plays an important role in learning. According to Dewey, the physical and social environments of a learning situation can be actively incorporated as contributors to the learning experience. Dewey points out how “environing conditions” help shape experience and urges teachers to understand and consider which “environments” can foster growth (meaningful experiences) – and how they can be arranged to support learning. This provides an important rationale for experimenting with and developing the “environments” in which science, including biology, is taught.

For this reason, *adventure education* programs and other field-based practices can be understood as forms of experiential learning. Dewey emphasizes that teachers must be aware that the situation and environment help shape the learning experience. This means, among other things, that teachers can use the environment to provide experiences that enable relevant development:

> “Above all, they should know how to utilize the surroundings, physical and social, that exist so as to extract from them all that they have to contribute to building up experiences that are worth while. ” (Dewey, 1938, p. 42).

Dewey illustrates how environment, situation, interaction, experience, and learning are closely connected (Dewey, 1938, p. 42). This implies that school and learning environments are crucial for learning. Environments hold rich opportunities for experiential learning.

This insight is not new. It is one of the reasons for creating interest and learning through informal learning environments such as exhibitions and activity centers. Informal learning environments, activity-based learning, and experience situations enable bodily and sensory approaches to understanding nature and science. With this article, we add the biological fabrication laboratory to the potential environments for experiential learning.

The Laboratory as an Environment for Learning and Experience

Traditionally, a laboratory is a scientific environment where function, technology, and equipment are integral to the creation of scientific truths (Latour & Woolgar, 1979; Law, 1993). In laboratories, learning experiences are structured around scientific procedures, the use of specialized instruments, and compliance with safety regulations. Such lab-based learning experiences are far removed from everyday forms of understanding and practice; they are not generally accessible. However, drawing on the FabLab movement and its democratizing intention of making digital technologies available to a wider public, Roskilde University has developed a different type of lab-based learning environment through the creation of a BioFabLab within the framework of FabLab RUC.

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FabLab RUC

The FabLab movement originated from a global DIY electronics community consisting of radio amateurs and electronics clubs. Later, “makerspaces” emerged, which more broadly applied digital technology (Davies, 2017; Turner, 2006), before the term *Fabrication Laboratories* (FabLabs) was popularized through the Massachusetts Institute of Technology’s (MIT) vision of workshops that can build almost anything. MIT has been a central driving force in the FabLab movement and helped develop *The Fab Charter*, which outlines the FabLab concept.

Every FabLab is different, but the main principles behind FabLab RUC are:

- Everyone has access regardless of background, and machine use is free.
- It should be easy to use – just come and share the machines, time, and space with others.
- Users do not need to justify their background for using the lab – all ideas are valid.
- There is no formal test-based certification system; instead, learning happens through apprenticeship, peer learning, and “learning by doing.”
- Dangerous machines and equipment can be used after appropriate verbal instruction or demonstration, depending on the equipment.

It is an open workshop for everyone – students, researchers, companies, and citizens in general – with a constant focus on actively and effectively lowering barriers to access. At FabLab RUC, users can develop and build prototypes as well as understand and use widely available technology in any way they wish. After five years of preparation, FabLab RUC opened in 2013 alongside the humanities-technology bachelor program (Haldrup & Svabo, 2012; Haldrup et al., 2018).

At the core of a good project in FabLab is the individual’s curiosity and exploration of the possibilities offered by the material and technology at hand. The intention is to integrate body and thought. It is a playful and exploratory approach to design (Hobye, 2014), often described as a “conversation” with the materials one works with (Schön, 1992). It is about being curious and practicing how to question and acquire knowledge.

BioFabLab

BioFabLab stands for *Biological Fabrication Laboratory* and is an extension of FabLab. The difference between BioFabLab and a traditional biology laboratory is that in BioFabLab, the starting point is more everyday – biological processes and tools accessible to laypeople. Variants of such biological labs resemble kitchens or greenhouses more than traditional labs. The goal of BioFabLab is to expand the materials and methods available in FabLab. It should be possible to work with biological media, living organisms, chemistry, and biological lab equipment. Whereas FabLab is centered on electronics, computers, and digital fabrication such as 3D printing, laser cutting, and CNC milling, BioFabLab focuses on living biological materials and organisms.

Empirical Examples

In the following, we describe two projects that concretely illustrate how experiential learning takes place in BioFabLab.

Fly Larvae: From Food Waste to Chicken Feed

This project was conducted by four third-semester students – three from the Social Sciences bachelor’s Program and one from the Humanities-Technology bachelor's Program (HumTek). Their supervisor was Ane Kirstine Åre, PhD, from the Department of People and Technology.

The purpose of the project was to investigate whether imported soy used for animal feed in Danish agriculture could be replaced with insects grown on source-separated organic waste, to strengthen sustainability and nutrient recirculation in production. The students examined the sociotechnical system, compared protein quality, and experimented with cultivating mealworms, crickets, and black soldier fly larvae on organic waste, using industrial chicken feed as a control. They concluded that it is technically possible to substitute soy protein with fly larvae, but that political and regulatory barriers currently prevent this.

Existing legislation restricts the use of insects for feed, and a lack of transparency makes it difficult for consumers to act politically and demand changes in production practices. Through their lab work, the students observed that the crickets and mealworms grew only minimally, while the mass of fly larvae increased 16-fold over 15 days. They also tested whether chickens would eat the larvae (which they did) and acquired important insights into the many complex factors involved in a biological production process. These included handling moisture problems, larvae crawling away or sticking, larvae pupating or flying away, varying water content in the feed fractions, and, if under-ventilated, rotting feed.

They achieved good, though not optimal, growth curves with a simple experimental setup. The students also gained valuable insights through discussions with a worm supplier about how new this field is. He shared his concerns, visions, and perspectives. Together, this provided insight into the complexity of the system they were studying. In their own words, it was “a challenge from the start to predict the whole course of the experiment, which made some periods very busy.” The group was especially excited that they generated their own data and empirical material: “It has generally been a really positive experience to see the possibilities for pursuing your interest and, for example, conducting experiments" (Bonde et al., 2019).

Materials and Methods: A metal shelf wrapped in vapor-barrier plastic and a plastic box for each experiment were employed. Moisture was initially regulated using a purchased humidifier connected to an automatic sensor; however, during the experiment, this was replaced with a hand sprayer used in each box to accommodate differences in the substrates. Temperature was controlled using a hairdryer connected to a thermostat and a power strip.

The project is documented on FabLab's website, where images and the student report can be downloaded: http://fablab.ruc.dk/bsfl/. The site also contains guidelines for building automation or other electronic controls.

General BioFabLab Reflections: This example illustrates how student interest, environment, and teaching activities interact in concrete experiential learning. It highlights a deliberate didactic prioritization of doing something rather than necessarily doing it perfectly from a disciplinary standpoint. In this example – and often in biology – cultivating organisms takes time, creating pressure when projects must be completed within a semester or in a shorter time. Getting the worms in their hands, experiencing the moisture and complexity of biology, and still managing to grow them contributed to more embodied, complex learning as well as joy and motivation.

The project utilized a simple setup of plastic boxes, an old shelf, and a humidifier, constructed by the students themselves. This simplicity minimized the need for support from us as technology supervisors, which allowed the students greater autonomy and agency, as they could themselves cut, tape, modify, and adapt the setup as needed.

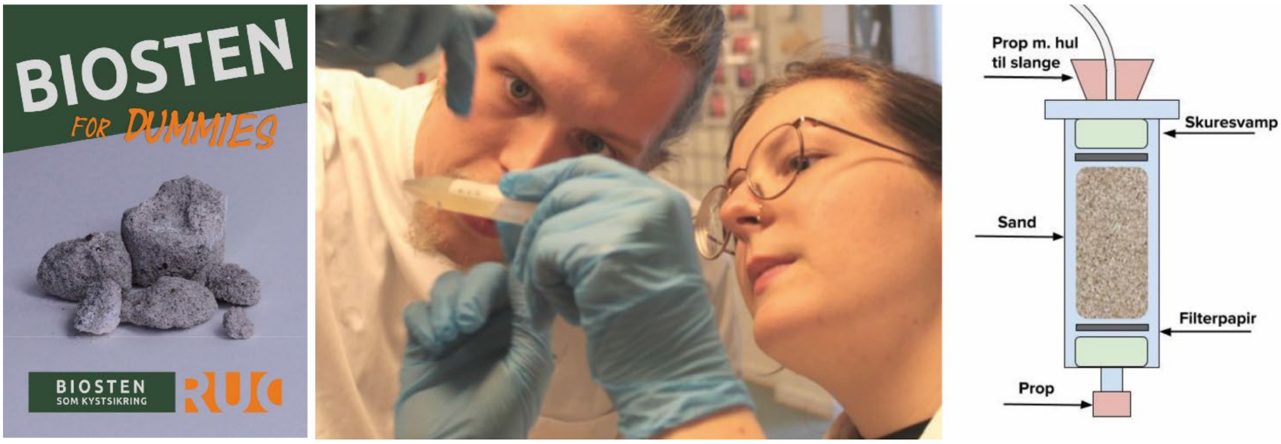

Illustration 1. *Biostone as Coastal Protection.* a) The group's short introductory guide to the subject. b) A sample under examination. c) Diagram of the home-designed growth and test chamber.

Biostone as Coastal Protection

This group consisted of six second-semester HumTek students. In addition to technology supervision from FabLab, they were guided by Tina Henriette Kristiansen, external lecturer at the Department of People and Technology, and Inger Louise Berling Hyams, external lecturer at the Department of Communication and Humanities.

The Project's Motivation, in the students' own words, was to "(...) explore sustainable solutions and technologies," and they chose biostone as their technological focus. *Biostone* is a popular term describing a biological cementation process. Bacteria are cultivated in a mixture of sand, calcium salt, and urea. The bacteria produce an enzyme that hydrolyzes urea, raising the pH, which leads to the precipitation of calcium carbonate (lime) that binds the sand together, forming a sandstone-like material.

The group produced their own “biostones” using an experimental setup they designed in collaboration with student assistants in BioFabLab. They sourced the bacteria (*S. pasteurii*) themselves and carried out several growth experiments. In their report, they presented perspectives on the technology in relation to creating organic architectural forms and cultivating sand-based furniture or other design objects.

Learning: The students had a positive experience working with a mix of technologies and materials, including electronics, programming, and bacteria, and they themselves became the connecting link between supervisors from different disciplines, such as biology, design, and technology. They discovered and wrote in their report:

> “…that biostone is not particularly difficult to make, as long as one has prepared thoroughly. The biostone can be made outside the laboratory and even in non-sterile conditions, and can thus be produced directly at a given location. Since *S. pasteurii* is not a pathogenic bacterium, the experiment can be conducted anywhere, even at home on the kitchen table, provided there is access to the necessary chemicals and equipment…” (Breum et al., 2019, s. 1).

Materials and Methods: To create biostone, the bacterium must be obtained from a bacterial collection. The bacterium is mixed with sand, calcium, and growth medium, and sterilized in a pressure cooker. Afterward, a urea solution is pumped through the sand in small amounts. The students utilized a basic Arduino-controlled peristaltic pump for this. Arduino is an open-source programming platform designed for accessible computer processing, often used in rapid prototyping. We maintain a supply of electronic components, procured cost-effectively through the internet.

Illustration 2. *Biostone Experimental Setup.* Laboratory glassware, disposable syringes, jam jars, and homemade electronics.

HumTek students are introduced to electronics, programming, and soldering, enabling them to set up such systems themselves. We have uploaded electronic guides and code examples to FabLab's website. The group has also created a short guide with material lists, available on FabLab's website and the study portfolio portal Thirdroom: http://fablab.ruc.dk/biostone-as-coastal-protection/ and https://ruc-thirdroom.dk/project/kystsikring-med-bio-stone/.

General BioFabLab Reflections: This group carried out several cultivation experiments. They mastered the technology, gained a more classical understanding, and had time to modify the setup multiple times. They entered a creatively generative process where their curiosity about what this biostone material would look like and how it would hold together was satisfied. They demonstrated that it is possible to pump bacteria and medium into non-sterile free sand, thus developing the idea of coastal protection. The setup itself was relatively complex, consisting of electronics, bacteria, sand, and growth medium, which required sterile handling.

Analysis

The purpose of BioFabLab is not to train biologists or biotechnologists, and the work described here should not be seen as a substitute for existing biology education. BioFabLab is not in competition with traditional analytical science programs. It is an environment that seeks to understand and develop how biology, living materials, and ecology can be brought into other disciplines. The aim is to create a space where playful, exploratory, and experimental engagement with science is made accessible to laypeople and students, based on their own curiosity.

This means that teaching activities are not primarily about copying a protocol, performing a set experiment, or using a particular piece of laboratory equipment or machine in a prescribed way. Rather, it is about making it possible to build a new machine or open and modify the one we have, and to look at biological knowledge and technologies, and, in combination with other fields, synthesize and create something that has not existed or been imagined before.

The examples illustrate a didactic and educational exploration of the laboratory as a learning environment, rooted in learners' engagement with and understanding of familiar environments (such as kitchens or greenhouses) and materials (plants, food, fungi, insects). Teaching activities are integrated into ECTS-accredited study modules, where the learning objective is not biology itself, but biology and the lab act as the environment and framework for learning.

Students acquire basic lab skills and knowledge as part of the overarching learning objectives of their courses, as well as knowledge of specific interdisciplinary connections. The activities are learning-oriented in the sense that learners' engagement forms the starting point for constructive, creative practice and reflection. Students are directly engaged in the lab environment, and teachers open a dialogue with them to develop knowledge, skills, and competencies. Students gain opportunities to work with disciplinary methods and tools, thereby developing their ability to participate in disciplinary and interdisciplinary collaboration, as well as their competence in identifying their own learning needs and structuring their own learning. According to the qualifications framework for higher education, these are the intended learning outcomes at bachelor's level (cf. link).

Activities are based on processes, tools, and materials that are more "everyday" than "scientific" and that are accessible. The scientific laboratory environment merges with everyday environments as sources of understanding, knowledge, and insight. The ordinary becomes an entry point to understanding more complicated and abstract relationships – such as biological and technological processes. This reinterpretation expands students' understanding of what a laboratory is, and it opens access both to the disciplinary complexity of working with biological material and to concrete disciplinary experience with it. Students also learn about the challenges of, for example, cultivating biological organisms in planned conditions.

Experiential learning involves an interplay between existing knowledge, personal interest, engagement, and motivation. One is thrown into deep water with whatever knowledge one already has and must make something of it within a short timeframe. The concrete fabrications form the pivot for ongoing exchanges between experience and reflection.

An important element is that students are introduced to open and exploratory approaches to learning and knowledge creation (Koskinen et al., 2011, p. 24; Shanks & Svabo, 2018). This entails working playfully, drawing on one's own and others' curiosity, and recognizing that the process is just as important as the final product (Kiib, 2004; Svabo, 2016). This is where one discovers what lies beyond what one could have thought of or what theory describes (Haldrup et al., 2018). It is also where one learns from mistakes.

This approach is particularly developed within design and technology development. It is a rapid prototyping approach, where one experiments with development processes without necessarily delving deeply into the underlying science. Well-known examples include the technology development culture in Silicon Valley and at Stanford University, where *design thinking* and its iterative *build-to-think* processes are key concepts in everything from technology to business development, as well as the *demo or die* culture at the MIT Media Lab.

The approach demonstrates that "...it is possible to do research with things at hand without complex justifications and theoretical grounds and just let the imagination loose in the workshop" (Koskinen et al., 2011, p. 24). The sandbox approach prioritizes hands-on, exploratory activities and often involves interdisciplinarity and hybrid fabrications.

Development occurs in fast iterations, but the strength lies in the interplay. It is not ideal to remain only in a rapid prototyping universe. One can build a model of a motor or an airplane wing with cardboard and duct tape, but constructing a jumbo jet requires thorough analytical and systematic research. Ideally, students experience a combination of different work modes: analytical mapping with meticulous notes in notebooks and lab journals, alongside open creative exploration.

The art lies in creating awareness of when one is in the open, creative process and when one is in the analytical or instrumental, goal-oriented process. This can be achieved by clarity in the process itself or by clarity in the physical space the student occupies. FabLab is the creative, generative space, in contrast to the office or group room, where critical and analytical work is in focus. Two different spaces where the path to success requires different approaches and methods.

This article – and the biological fabrication laboratory at RUC – connects scientific and biotechnological learning to rapid prototyping and sandbox approaches from design and technology development.

Perspectives and conclusions

Challenges

One of the challenges is whether the laboratories are as open and accessible as intended. For example, some students report that understanding how to use FabLab can be challenging. How do you avoid getting in the way or disturbing staff or other users? How do you acquire the knowledge needed before you can move freely in this space? In many ways, you step into an open and exploratory field that you must navigate yourself, where there aren't many predefined answers. Part of the intention of this approach is to soften the boundaries between disciplines and not require a fixed body of knowledge before engaging in experimentation. The downside is that this can create insecurity among students who are not familiar with situations where solutions are not given in advance, but where the activity is curiosity-driven. The goal lies in the material exploration and processing itself.

Growing interest from other fields

We see a strong interest in creative work with biological materials, media, and organisms. Many of those who reach out to BioFabLab are not doing biological research but instead exploring what biology and biotechnology can offer within their own fields. In that context, an open and informal lab that emphasizes DIY and everyday approaches has wide appeal.

Architects, designers, and artists want to work creatively and experimentally with biology, exploring questions about our relationship with nature and other species through materials. A sense of this interest can be seen in initiatives such as the "Bioart & Design Award" or the "Biodesign Challenge." In the project *Grow your own cloud*, for instance, designers speculate on how future data centers might store information in the DNA of plants or trees (Clarke et al., 2019); and in the art installation *Microbial Machine*, artist Naja Ankarfeldt (2019) works with bacteria-grown textiles. In recent years, several exhibitions have also investigated society's understanding of biology, examining it at the intersection between art, research, and technology. Examples include *OU\ /ERT* at Transpalette, Contemporary Art Centre in Bourges, France, *Hybrid Matters* at Nikolaj Kunsthal in Copenhagen, and *MATTER(S) matter(s): Bridging Research in the Arts and Sciences* at MSU Broad Museum, USA.

Difficulties in creating prototypes with biological materials

A certain level of expertise is required for this type of interest-driven project, as it can be demanding to keep biological material alive and thriving. Biology cannot simply be put on hold and saved for the following week. It must be kept alive continuously, which demands both continuity and persistence from BioFabLab and its users. That is why BioFabLab is currently working on developing model organisms as biological tools and materials that users can work with themselves. These might include algae, bacteria, yeast, water fleas, ants, selected plants, and more.

Conclusion

Over the past two years, BioFabLab has been established within the framework of FabLab RUC.

It has successfully connected to a global trend where biology is being explored in other disciplines, attracting interest from students, researchers in fields such as design and architecture, and universities outside Denmark

We have presented two projects that demonstrate how students not studying biology were able to incorporate biological organisms, bacteria, and worms into their work. They were given access to biology early in their project phases, enabling them to create and modify various experimental setups themselves. They gained an understanding of how biology works, the growth rate, the need to work carefully under sterile conditions, and the significance of factors such as temperature and humidity. Their projects shifted between theoretical academic work and experience-based exploration, making both forms of learning and knowledge creation present in their work. In the future, we will continue developing biological tools, organisms, and methods that we can put into students' hands.

The development work in and around BioFabLab helps demonstrate how students can engage with science and technology in exploratory, interest-driven, hands-on, and student-led ways. One issue that has emerged in internal discussions about the scientific learning conducted in BioFabLab is the question of educational levels. Is BioFabLab only relevant for bachelor-level students and below? Is it mainly relevant for non-science students? How might some of the strengths of informal lab learning be applied in high school? In primary school?

In relation to teaching practices in high schools and primary schools, presenting BioFabLab's development work is an open invitation to exchange dialogue, knowledge, and experience. Teachers can delve deeper into the ideas behind FabLab and BioFabLab, as well as each project. There could also be opportunities to explore experiential learning in larger collaborative development projects—or merely to drop by and work on their own projects!

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