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Human–Material Dialogues Through the Use of Robotics

Embodied Craft Learning in an Architectural Educational Context Exploring Patterns in Clay

ABSTRACT
This research investigates and discusses an embodied craft learning situation in an educational context that aims to support students within architecture by applying human–material dialogues when using robotics. Initially, the students were introduced to traditional craftsmanship based on materials and tools in ceramics. Based on the gained experiential knowledge, the same tools and materials were applied and explored on a UR 5 robot. A sensor provided the students with the opportunity to interact with the material through the robot while it was operating. The learning situation showed the potential to teach the students about robotics based on human–material dialogues and embodiment through making. The sensor enabled the students to use their experiential knowledge to improvise and work intuitively and spontaneously while they were exploring patterning based on the tools attached to the robot and the responsive material.

Keywords:
Robotics, ceramics, crafting, embodied learning, human-material

INTRODUCTION

Digital technology has become highly relevant in various artistic design and craft processes, including ceramic craft practice (Keep, 2019; Warnier et al., 2014). The use of digital technology advances and enables solutions for creating complex designs and forming solutions. However, there seems to be a gap between traditional craft practice and digital technology since machinery prevents the craftsperson from interacting directly with the material in question.

In this context, craft practice concerns the close relationship between a craftsperson and material; a dialogue between the body and material exists as an embodied experience of making in which the craftsperson directly interacts with the material as a partner in the design process (Brinck & Reddy, 2020). Within traditional ceramic craft practice, the relationship between a craftsperson and material is characterised by an intimate relationship because of the often straightforward hands-on tactile use of material, where the craftsperson is guided by their interaction with a responsive material (Dormer, 1994). Crafting and execution work together in an intuitive and humanistic way (Leach, 1976). Thus, ceramic craft practice is a creative process based on experiential knowledge in which the craftsperson works intuitively to enable spontaneous actions and improvisation (Johns et al., 2014).

On the other hand, digital tools enable a craftsperson to work with a high degree of complexity that is impossible with traditional techniques and manual workflows. At the same time, the use of new technology tends to create a barrier between the craftsman's direct relationship to and use of the material since making is based on machinery (Johns et al., 2014; Leach, 1976; Sennett, 2008), which usually does not allow immediate interaction with the materials.

Thus, an important question is how to combine traditional craft practice with the high-accuracy and complex design options that characterise robotics to enable spontaneous actions and improvisation and enhance traditional craftsmanship.

In this study, we explore and discuss a workshop setup for an embodied craft learning situation in an educational context that aims to support students within architecture in applying human–material dialogues when using robotics based on traditional ceramic craft practice. Within architecture, digital technology has become a common tool for prototyping, which might prevent a direct relationship to material within the design process and flatten our multisensory capacities of imagination, as discussed by Pallasmaa (2005). Nevertheless, robotics allows us to customise our tools as we want them, which encourages us to rethink our role in using and developing these processes (Johns et al., 2014). Thus, instead of thinking of craft and technology as diametric positions, we see technology as an enabling force, following McCullough's (1998) idea of a close connection between digital work and craft practice.

In this way, robotics makes up a valuable opportunity to set up a workshop for exploring an embodied craft learning situation based on robotics inspired by human–material dialogues within traditional ceramics craft practice since it is easy to apply traditional craft tools on a robot arm. Furthermore, robots enable a workflow that includes creative coding as an art-making process, as discussed by Dufva (2018). Nevertheless, we will simplify the overall setup in this context and concentrate on the human–material dialogue. The overall setup will be based on a combination of preset robotic paths and a human-controlled approach as key explorations in the educational context. The workshop is organised as a one-day event by two researchers for eight architecture students. One researcher specialises in ceramic craft and digital technology, while the other specialises in architecture and digital fabrication methods. In addition to contributing to the education of the students, the workshop aims to explore the idea of an embodied craft-learning situation using robotics based on traditional ceramic craft practice.

DIGITAL CERAMIC CRAFTSMANSHIP

Researchers and artists have successfully investigated examples of craft practices that integrate digital technology. An example is the work by Zoran and Buechley (2013); it combines digital fabrication and craft involving object destruction and restoration. Zoran and Buechley (2013) merged two approaches: creating and breaking vases and then three-dimensional (3D) scanning and tracking broken surfaces to create restorative elements based on a 3D printed nylon, a process they termed *hybrid reassemblage.* Although their approach is highly relevant, it deals with something other than focusing on the actual making, where a craftsperson directly interacts with and is guided by responsive material. In this way, their approach differs from the focus of this study.

Another example is 3D clay printing, a representative example of how crafts practitioners can interact with materials while printing. Falin et al. (2021) described the potential to improvise within the process of 3D printing, for example, by directly influencing the material flow, managing the air pressure, changing the printing speed or making manual interventions to the print and printing bed. However, sculpting tools based on traditional ceramic practices were not used (Falin et al., 2021). Thus, the project did not enhance traditional craftsmanship.

A third example is transforming traditional tools for sculpting using clay into advanced tools for robotic sculpting. In the project RobotSculptor: Artist-Directed Robotic Sculpting of Clay at Gramazio Kohler Research, a loop tool was utilised for advanced robotic sculpting in clay (Ma et al., 2020). A style for sculpting was developed, and the sculpting process was then automated and executed using the robot's arm (Ma et al., 2020). However, the sculpting process was based on something other than the craftsperson's direct interaction with the material since it was automated.

The examples mentioned above are representative of how craft practice integrates the use of digital technology. Nevertheless, the examples do not combine a craftsperson's direct interaction with the material by using traditional tools simultaneously when utilising digital technology, which is the focus of this study for enhancing traditional craftsmanship. A possible solution is to utilise traditional tools attached to a robot arm combined with a device that enables the craftsperson to interfere in the process while the robot is operating. This study explores how a sensor enables a craftsperson to manipulate a robot's actions in real time based on the distance between the hand and the sensor. The experiment is based on pattern-making on a clay surface with various tools attached to the robot arm.

METHOD

The method is experimental and based on practical design experiments using a UR 5 robot, a measurement sensor and a graphical user interface to control the robot and sensor, clay and traditional tools for making imprints in clay. In the learning situation, the students take part in the experimental design practice based on a setup defined by the teachers in charge (see Image 1). Design practice is used as a method of inquiry and reflective practice in which the students reflect through and on the action (Schön, 1983). 'Design practice is a way of inquiring, producing knowing and knowledge' (Downton, 2003, p. 1) and is used as a material practice for knowledge production (Koskinen et al., 2008). Thus, design experiments are concerned with moving away from the known by creating examples of what could be done and how and by making general suggestions about a change to design practice (Binder & Redström, 2006).

EXPERIMENT

The experiment in question is based on a study with a group of first-year bachelor's students within the field of architecture that investigated the gap between traditional and digital craftsmanship and how this gap might be joined through robotics. The overall frame of the experiment was defined by making patterns on a clay surface using different tools that are usually used in the field of ceramics (see Figure 2).

The experiment was divided into two steps. The first step was an initial workshop about becoming experienced within traditional craftsmanship and using the material and tools in question. The second step was an experiment exploring how the experiential knowledge gained from the initial workshop could be utilised to enhance crafts practice using robotics.

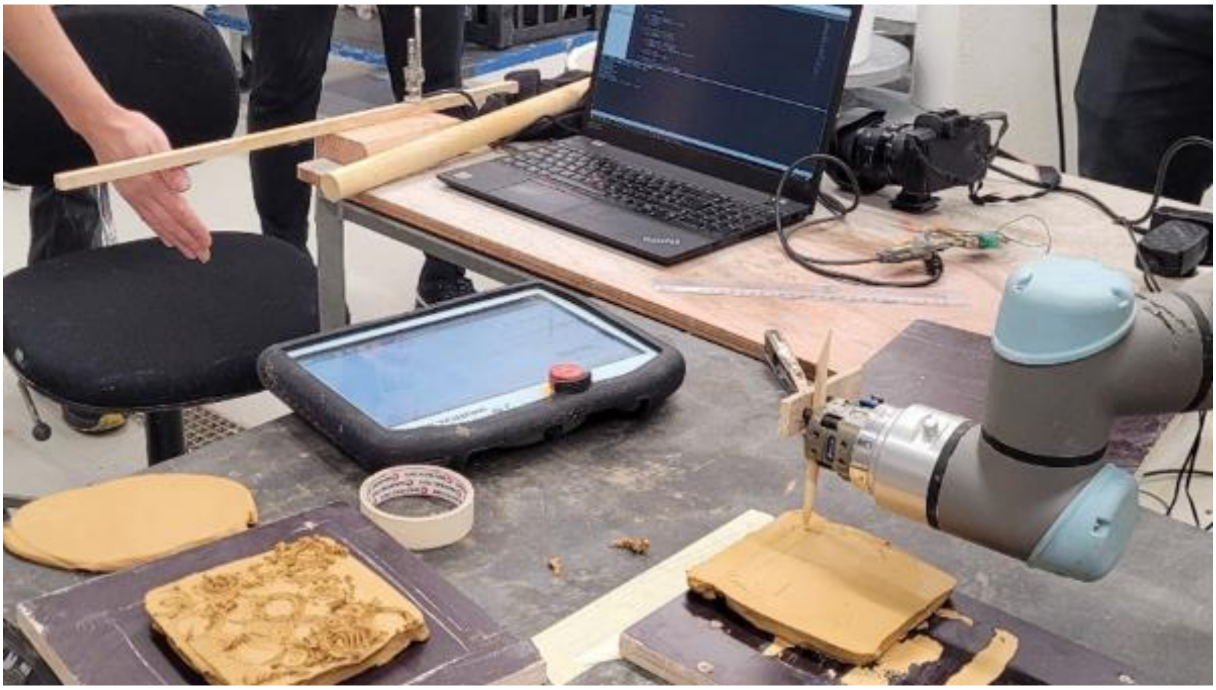

FIGURE 1. The overall setup defined by the teacher in charge consisted of the UR 5 robot, a sensor, the graphical user interface, clay and traditional tools for making imprints in clay.

FIGURE 2. Examples of tools often used in the workshop for making imprints within the field of ceramics.

Initial workshop

Initially, the students participated in a workshop using traditional and analogue tools. Thus, this part of the workshop did not involve any digital tools. In the initial workshop, they explored possible surfaces and textures that could be achieved by pressing tools into the clay surface in various ways. The approach was explorative, aiming to reveal and explore what could be done with the material through practical experimentation.

The results of the initial workshop included various possible patterns based on the tools and reflected the experiential knowledge the students obtained through their experimentation (see the examples in Figure 3). Thus, the students were introduced to a design approach based on a material practice that enabled them to work intuitively and allowed for spontaneous actions and improvisation. Simultaneously, the students became experienced with and familiar with the traditional way of making clay imprints, which they could transfer to the experiment's second step with the robot.

FIGURE 3. Examples of patterns from the initial workshop based on the objects used as tools for making imprints.

Robot experiment

For the experiment with the robot, the students were introduced to the overall setup, consisting of the UR 5 robot with a device to attach tools (see Figure 4), a graphical user interface connected to the robot and a displacement measurement sensor from SICK that captures movement within a range between 100–400 mm (see Figure 5). The graphical user interface was developed with Grasshopper, a plugin for the 3D modelling software Rhino.

For the experiment, several paths for the movements of the robot's arm were predefined, such as a movement that created a spiral or a grid of lines. The paths for the robot's movement were all defined by points where the tool moves towards the clay surface with a predefined distance of, for example, 2 cm without touching the clay surface. When the hand activates the sensor, the tool moves into the clay surface in relation to the hand's distance from the sensor. The closer the hand is to the sensor, the deeper the tool will move into the clay.

While the robot's movement was predefined, the students could choose the tools they wanted, for example, the tool they favoured in the initial workshop and with which they were experienced. Nevertheless, the students decided which path to explore concerning their tools. Although the robot's paths were simple, they represented and utilised the high-accuracy and complex design options that the robot provided and enabled a focus solely on exploring the results of the interventions through the use of the sensor.

Furthermore, the reason for the predefined robotic performance was twofold. First, the students were first-year students and not experienced in programming, robotics and clay. Through their education, they will learn programming in Grasshopper. Through this setup, we would like to encourage the students to originate their approach using digital technology based on materials and traditional craftsmanship rather than complex coding, which might not be able to be realised in the intended materials, and without allowing the materials to have a say in the structures we create (DeLanda, 2004).

Second, the simple setup is a representative experimental setup in which the students are encouraged to explore a few parameters at a time. We know that a simple setup limits the human–material dialogue by, for example, excluding pressure sensing. On the other hand, the predefined robotic performance and the clear input by the participant reflect a simple setup as a conversation between the input by the hand and the robot imprint. The preset robotic path with its logic has to be explored through the student input and as a creative meeting point of robotic behaviour and human crafting. Building up and developing an experimental complex setup in a way that produces knowledge that we do not yet have requires acquired intuition based on experience (Rheinberger, 2012), which we suggest being built up over time based on simple setups. Thus, the idea is also to introduce how a simple setup makes up a helpful base for developing a larger and more complex experimental setup.

FIGURE 4. The robot arm has an attached tool for making imprints on the clay surface.

RESULTS

The experiments resulted in various examples. The pattern in Figure 6 explores a single spiral with an attached star-shaped tool. This example shows how the precision of the spiral gives the freedom to explore the imprint through improvisation using the sensor tool. While the robot arm's movement gradually designs the spiral into the clay, the artist can intuitively explore and modify the depth through improvisation. This allowed the imprint of the star-shaped tool to change from a dot to star shapes that interfered with each other. The result reflects a dynamic balance between the path and the imprint, where the pattern made by the tool nearly dissolves the path, so it is only slightly recognisable.

The pattern in Figure 7 shows the exploration of a simple path of a point in a linear grid, which is repeated numerous times. Thus, the pattern is intuitively developed to different depths through improvisation over time. The points are closely placed in the grid, which makes the single imprints from the tool overlap in a way that pushes the clay into the neighbouring imprints, making their shape slightly organic according to the materiality of the clay. The improvised expression developed in conjunction with materiality constitutes a dynamic interplay with the high precision of the robot.

The pattern in Figure 8 builds on the same path and approach as the example in Figure 7, but the tool is angled. The results show how a slight change makes a significant difference. Since the tool is angled, new unpredictable shapes develop between single imprints. The combination of different shapes and angles reflects a high degree of complexity that, as in Figure 7, is structured by the underlying path and precision of points, which provides an excellent opportunity for improvisation.

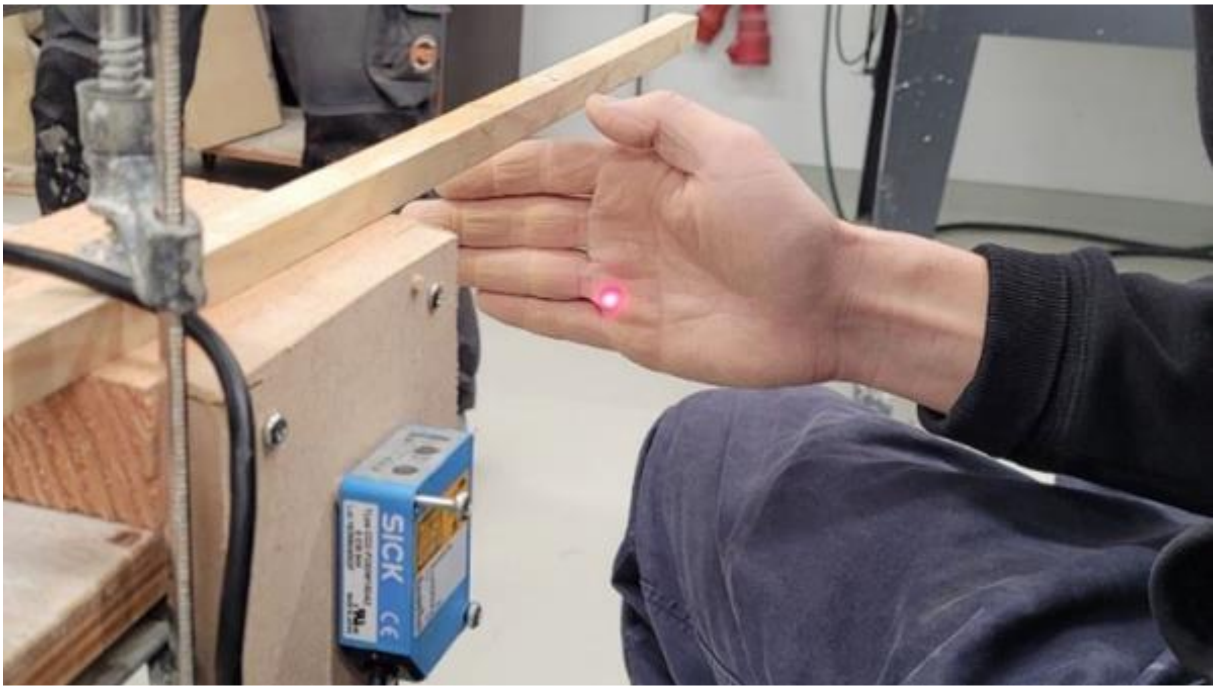

FIGURE 5. The sensor is connected to the graphical user interface and enables the user to affect the robot's action.

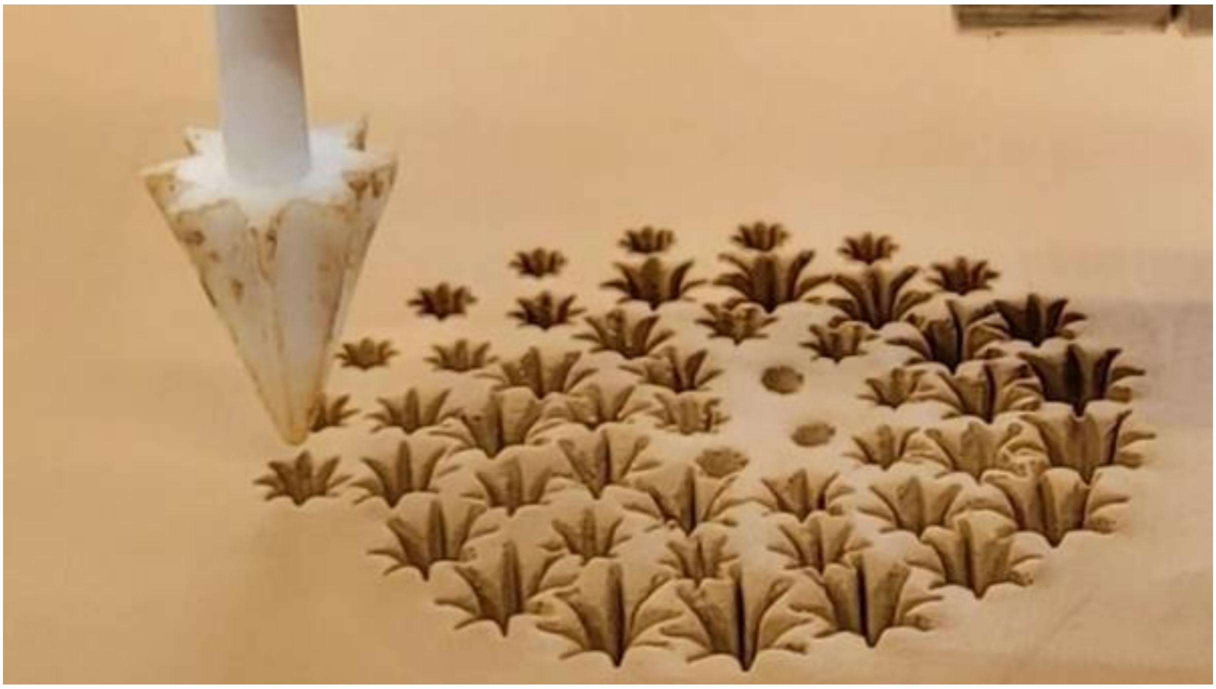

FIGURE 6. The robot arm with an attached tool for making.

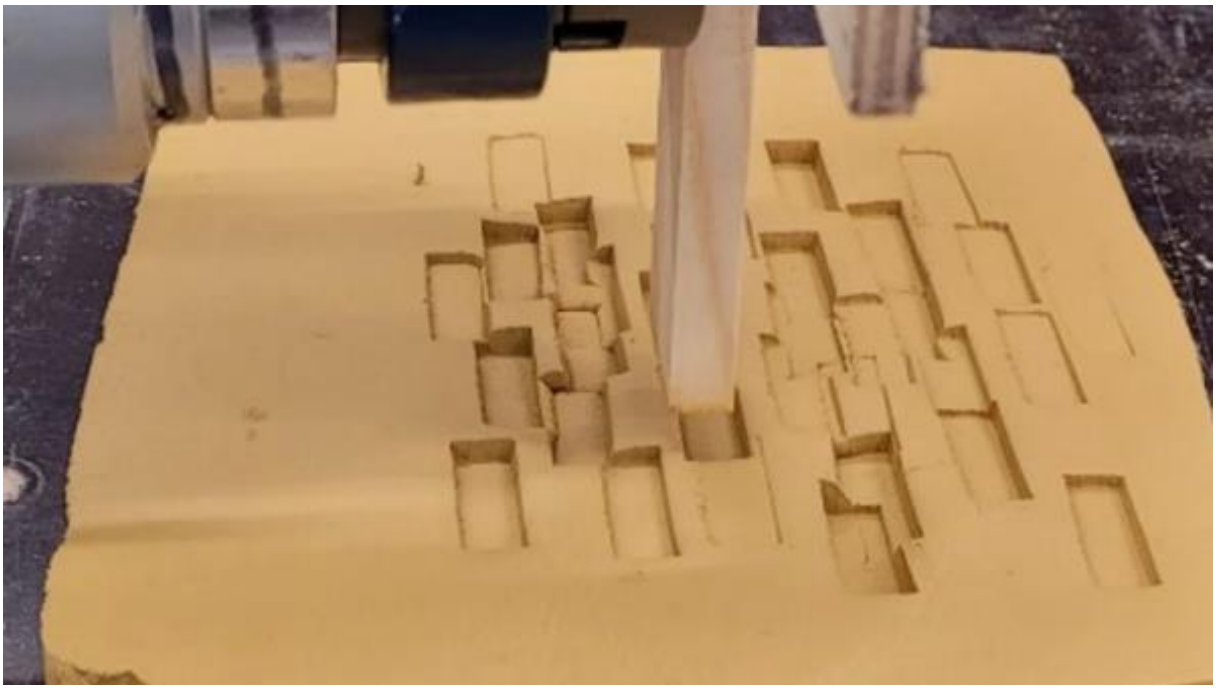

FIGURE 7. The sensor is connected to the graphical user interface and enables the user to affect the robot's action.

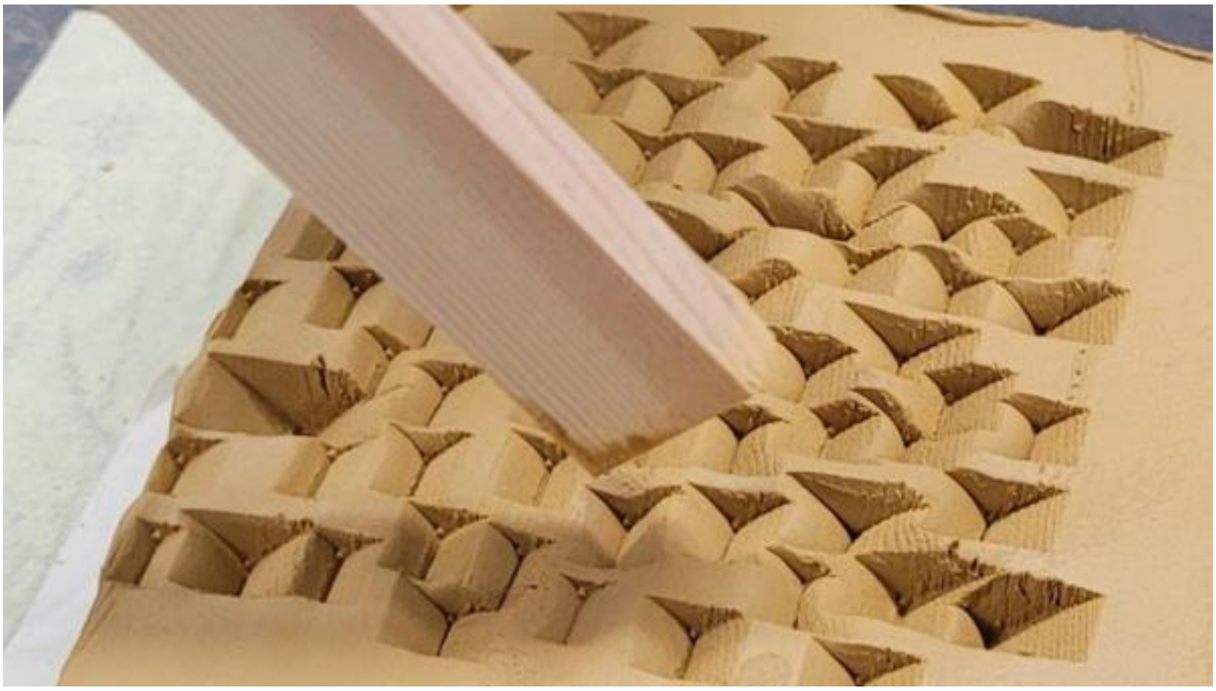

FIGURE 8. The robot arm has an attached tool for making imprints on the clay surface.

DISCUSSION AND CONCLUSION

This research explores an embodied craft-learning situation in an educational context that aims to support students within architecture in applying human–material dialogues when using robotics based on traditional ceramic craft practice. In the experiment, we used a UR 5 robot arm; a sensor provided the user with the opportunity to interact with the material through the robot while it was operating.

The overall experimental setup of the learning situation has demonstrated a valuable way of introducing human–material dialogues when using robotics. Initially, the students were introduced to traditional craftsmanship based on materials and tools in ceramics. Based on the gained experiential knowledge, the same tools and materials were applied and explored on a UR 5 robot.

As researchers, we found that learning from the initial workshop made up a helpful base for the robot session. We will emphasise the initial workshop as a promising approach since it enables an understanding of a hands-on approach and a bodily understanding of the intimate relationship between body and material. The tools and the learning of material behaviour were utilised in exploring the predefined path in which the sensor enabled the students to use their experiential knowledge to improvise and work intuitively and spontaneously while exploring patterning based on the tools and the responsive material. For example, the result of an imprint that pushes the clay into the neighbouring imprints was closely explored with attention in the initial experiment and subsequently in the robot experiment.

Furthermore, we will emphasise the simple setup, focusing on the combination of predefined robotic paths and the human-controlled imprinting approach. The sensor aimed to preserve the intimate relationship between body and material, which enabled the students to improvise and explore the underlying predefined, highly accurate pattern based on the responsive material. As mentioned earlier, we know that such a simple setup limits the human–material dialogue by, for example, excluding pressure sensing. However, on the other hand, it enabled a focus on the creative meeting point of robotic behaviour and human crafting.

The physical results of the experiments were characterised by patterns that expressed a dynamic balance between the accuracy of the robot and the imprints by the tool, which nearly dynamically dissolved the path because of the tool's shape and the responsive and lively material. In this regard, the work is valuable for a human–robotic dialogue based on the material. Thus, the simple setup demonstrates the potential for robotic accuracy in very detailed and complex patterns, which, in conjunction with spontaneous actions and improvisation through the bodily movement of the hand, enhances traditional craftsmanship.

Finally, we see the idea of the simple setup as a beneficial approach for introducing an experimental approach in which the students explore a few parameters at a time. Thus, a simple setup is a helpful base for developing a larger and more complex experimental setup.

In future research, it would be interesting to extend the learning situation by including coding a robot's predefined path. In this study, we focused on human–robotic dialogue, but this could be broadened to include creative coding as an art-making process, as discussed by Dufva (2018). Furthermore, exploring the development of the resulting patterns in an architectural context could be interesting.

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