The Reflective Maker: Using Reflection to Support Skill-learning in Maker Spaces

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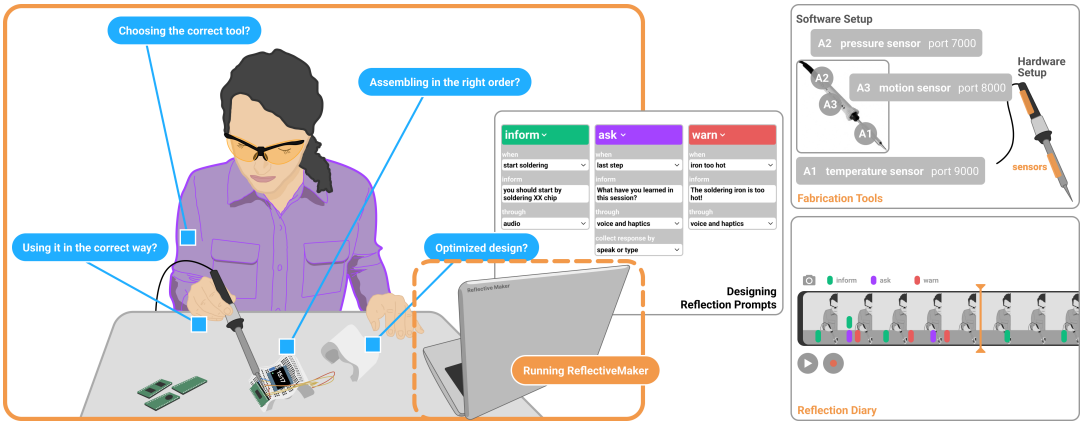

Figure 1: We present *ReflectiveMaker* - a toolkit for experts and educators to design reflection exercises for novice learners in makerspaces. Experts and educators can use *ReflectiveMaker* to design the reflection prompts during fabrication activities, sense the user's activities, identify suitable events for prompting reflection, record the user's reflections, and analyze data on their learning progress.

ABSTRACT

In recent years, while HCI researchers have developed several systems that leverage the use of reflection for skill learning, the use of reflection-based learning of maker skills remains unexplored. We present *ReflectiveMaker* - a toolkit for experts and educators to design reflection exercises for novice learners in makerspaces. We describe the three components of our toolkit: (a) a designer interface to author the reflection prompts during fabrication activities, (b) a set of fabrication tools to sense the user's activities and (c) a reflection diary interface to record the user's reflections and analyze data on their learning progress. We then outline future work and envision a range of application scenarios.

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CCS CONCEPTS

• **Human-centered Computing** → **User interface toolkits**.

KEYWORDS

reflective learning, makerskills, makerspaces

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1 INTRODUCTION

The role of reflective exercises in supporting learning is widely studied in HCI. This has led to the development of several theories to understand reflective processes [2, 10], frameworks to leverage reflection for improving learning [4], and systems to nudge reflective exercises during different tasks, such as musical skill development [5], and professional development [9]. However, these ideas have not been explored in the context of maker skills learning.

We bridge this gap through *ReflectiveMaker* - a toolkit to create reflection exercises for novices to complete during their maker projects. In particular, these reflection exercises prompt the users to reflect on their actions during the designing, prototyping, and fabrication stages. To inform the design of this toolkit, we conducted a semi-structured interview with an experienced educator who frequently uses reflection exercises to support skill learning in makerspaces and fab-labs. Our interview findings highlighted that reflective exercises could be most useful for supporting learning for novices (1) in open-ended design projects (for example, building a bird house) (2) while making design decisions (for example, choosing the right electronic components), and (3) for improving knowledge of best practices for tool usage (i.e., knowing the right tool for the right task).

Based on these findings, we are building *ReflectiveMaker* - a toolkit that allows educators or experts to design reflective exercises for novice learners during prototyping and fabrication processes. The toolkit comprises three components: (1) a designer interface to develop reflection prompts and set the reflection events, (2) a set of fabrication tools with embedded sensors to identify when moments to prompt reflection are encountered, and (3) a reflection-diary interface to record and analyze the learner's reflections. We present three case study applications where our toolkit can be useful for improving self-knowledge, task understanding, and tool expertise in makerspaces.

In this project, we contribute:

- A toolkit for designing the reflective exercises using: (1) our designer interface (2) our set of fabrication tools (3) our reflection-diary interface;
- Case-study applications to demonstrate the use of our toolkit to design reflective exercises and support learning.

2 RELATED WORK

Our work builds upon existing HCI research on reflective learning, systems for reflection, and systems to support skill learning in makerspaces.

Reflection has been defined as "a conscious, purposeful thought directed at a problem" [4] and "a process in which people recapture their experience, think about it and evaluate it" [1]. A reflective process is a form of conversation that occurs either in-action and on-action [10]. A reflective exercise, which consists of sequential thoughts [2], can be prompted through self-dialogue or social discourse (for example, with an instructor) or through human-computer-interaction (for example, with a system) in order to achieve the learning goals, such as improving knowledge and performance, or reducing errors.

To support novices with skill learning in makerspaces, researchers have developed several systems that provide support for tasks such as prototyping, breadboarding, tool usage, etc. For example, ToastBoard [3] helps with the correct placement of components by visualizing connectivity between components and also shows the voltage at each point in the circuit. HeyTeddy [6] helps with circuit wiring by providing voice assistance to the user and also requests the user to confirm that they finished a certain step. Similarly, CircuitStack [11], and VirtualWire [8] supports users with wiring or re-configuring circuit wiring. Recently, the concept of smart makerspaces has also been proposed by researchers where the learners are provided with guidance during their maker tasks [7]. However, these systems do not prompt reflection, which is the gap we address in our work.

Through *Reflectivemaker*, we explore the idea of facilitating a reflective exercise using a system that prompts the learner to reflect on their actions and decisions while working on open-ended design projects.

3 THE REFLECTIVE MAKER TOOLKIT

To inform our toolkit design, we first conducted a semi-structured interview with an educator at a makerspace at our institution who advises undergraduate and graduate students on their design projects. The goal of this interview was to learn how they use reflection in instruction and to identify these key moments when reflection is most valuable for novices. Our findings reveal three scenarios in which reflection is most important: (1) in open-ended design projects (for example, building a bird house) (2) while making design decisions (for example, choosing the right electronic components), and (3) for improving tool usage knowledge and expertise (for example, knowing the right tool for the right task). Based on these findings, we designed a toolkit that allows educators or experts to design reflective exercises for these key moments. The toolkit contains the following three components:

3.1 Design Interface: *For Designing Reflection*

Experts and educators in makerspaces can use this interface to design reflection exercises for novice learners during maker tasks, such as placing electronic components using a soldering iron (Figure 2a). Designers can start by choosing the tool for sensing the learner's actions. They can select the tools from a set of tools we provide in our toolkit. They then set the sensor reading levels at which the learner should be prompted to reflect upon their action. The prompts can ask, inform, or warn the learner. The designer can choose from a set of pre-designed prompts or modify and add their own. The designer can also choose how to record the learner's reflections, i.e., through text, audio, or video. Once the sensor modality, the prompt design, and the recording modality are decided, the designer can save the reflection exercise and add more prompts if needed.

3.2 Set of Fabrication Tools: *For Sensing User's Actions and Providing Reflection Prompts*

We also provide a set of embedded power tools, for example, a soldering iron with an accelerometer, gyroscope, temperature sensor, and force pressure sensor (Figure 2b). These embedded tools with sensing abilities provide more information about the learner's task performance, such as holding the tool incorrectly or using the tools with incorrect settings. Our system interfaces with this set of tools provided in our toolkit and monitors the sensor readings. The toolkit provides have three tools, namely, a screwdriver with a pressure sensor, a power drill with a pressure sensor and vibration sensor, and a soldering iron with the sensors listed above. New Mention tools can be easily built and added to the system depending on

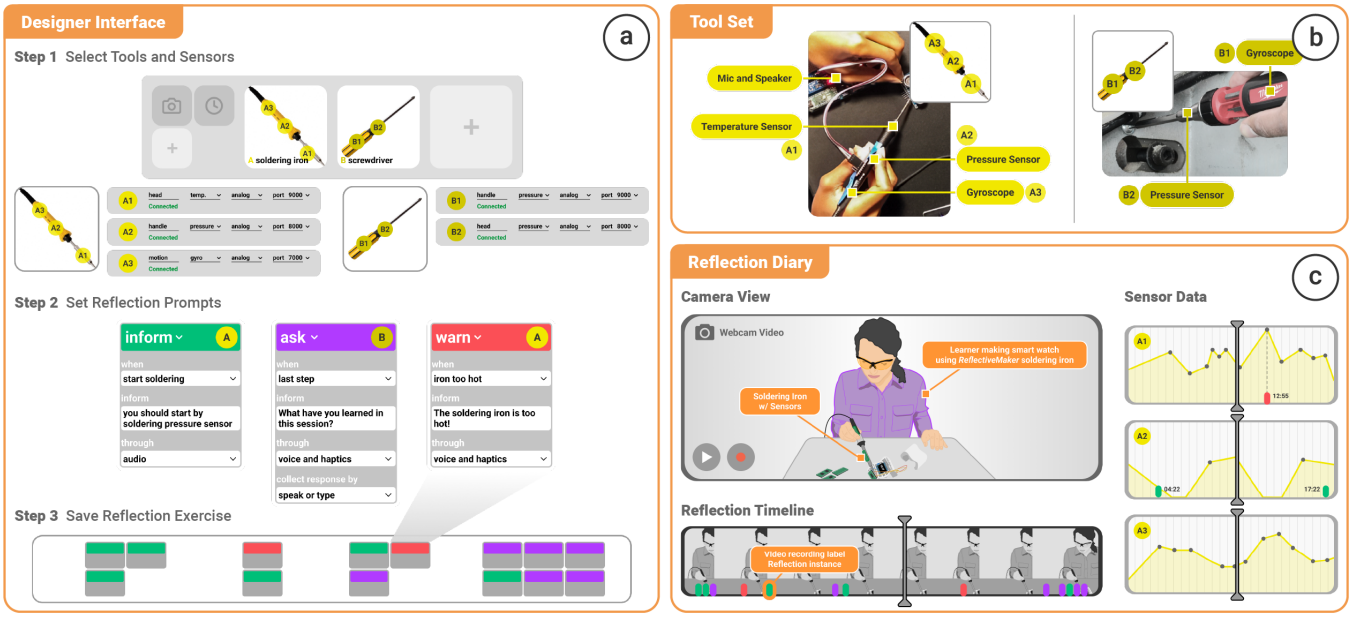

Figure 2: The *ReflectiveMaker* toolkit has 3 parts: (a) a designer interface to author the reflection prompts during fabrication activities, (b) a set of fabrication tools to sense the user's activities and (c) a reflection diary interface to record the user's reflections and analyze data on their learning stages.

what's available in the makerspace. The designers can select which sensors' readings to monitor and at what reading levels to trigger the reflection prompts. Our system also interfaces with the webcam on the learner's laptop to record the learner's actions, prompt the learner (either via text prompts or audio prompts), and record their reflection responses (either via text prompts or audio prompts). Every time the learner encounters a reflection prompt, their reflection responses get recorded in text or audio format in our system.

3.3 Reflection Diary: For Recording

This interface allows both - the designer and the learner to access the recorded reflections along with the other information related to the task, such as the sensor readings, the timestamps, and the task recordings (Figure 2c). By re-visiting the recorded reflections and analyzing them with other contextual information, one can gain deeper insights into the learner's knowledge and skill levels. This interface provides an opportunity to track the learner's progress over time through reflections.

4 CASE STUDY APPLICATIONS

Below, we envision potential applications (Figure 3) where *ReflectiveMaker* can support learning.

Architectural Projects: *ReflectiveMaker* can support architecture students by engaging them in structured reflective exercises during the design development phases, and prompting them to reflect on their design by *asking* open-ended design questions (Figure 3a). The students engaging in reflective exercises when making physical model can learn design through the process of making.

Interactive Art and Media Projects: *ReflectiveMaker* can assist students learning about physical prototyping by prompting them to reflect on the making steps while also *informing* them about the sequence of steps to follow (Figure 3b). By engaging the students in sequential reflective exercises as they go through the making steps can facilitate better understanding of the making process.

Engineering and Product Design Projects: *ReflectiveMaker* can guide students working on the engineering and product design students as they iterate through several their design prototypes. By engaging them in reflective exercises on component choices and placements, and *warning* them about incorrect tool usage, our toolkit can scaffold skill learning in makerspaces (Figure 3c).

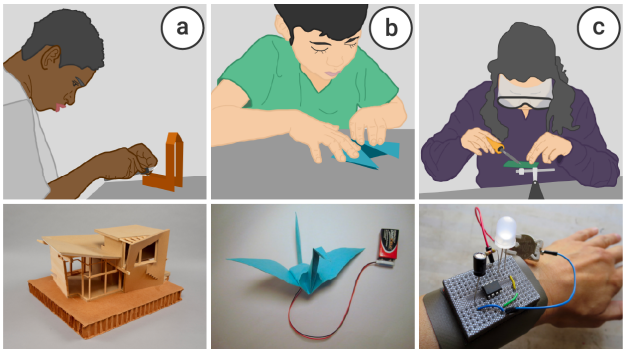

Figure 3: Case study applications: *ReflectiveMaker* can support learning for students working on: (a) architecture design projects, (b) engineering & product design projects, and (c) interactive art & media projects with physical computing.

5 CONCLUSION AND FUTURE WORK

We presented *ReflectiveMaker*, a toolkit support reflection-based learning for novices in makerspaces. Experts and educators can use *ReflectiveMaker* to design the reflection prompts during fabrication activities, sense the user's activities and identify suitable events for prompting reflection, and record the user's reflections and analyze data on the learner's progress over time. For our future work, we will conduct an extended formative study with 3-6 instructors in makerspaces to better understand the role of reflection in learning during making. We are also developing a framework to design reflection prompts that provide learning opportunities during maker activities. We will evaluate the usability of our system through controlled user studies. We will also explore how *ReflectiveMaker* could support larger group and hybrid educational opportunities.

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REFERENCES

[1] Eric P.S. Baumer, Vera Khovanskaya, Mark Matthews, Lindsay Reynolds, Victoria Schwanda Sosik, and Geri Gay. 2014. Reviewing Reflection: On the Use of Reflection in Interactive System Design. In *Proceedings of the 2014 Conference on Designing Interactive Systems* (Vancouver, BC, Canada) *(DIS '14)*. Association for Computing Machinery, New York, NY, USA, 93–102. https://doi.org/10.1145/2598510.2598598

[2] John Dewey. 1933. *How we think: A restatement of the relation of reflective thinking to the educative process.* DC Heath.

[3] Daniel Drew, Julie L. Newcomb, William McGrath, Filip Maksimovic, David Mellis, and Björn Hartmann. 2016. The Toastboard: Ubiquitous Instrumentation and Automated Checking of Breadboarded Circuits. In *Proceedings of the 29th Annual Symposium on User Interface Software and Technology* (Tokyo, Japan) *(UIST '16)*. Association for Computing Machinery, New York, NY, USA, 677–686. https://doi.org/10.1145/2984511.2984566

[4] Rowanne Fleck and Geraldine Fitzpatrick. 2010. Reflecting on Reflection: Framing a Design Landscape. In *Proceedings of the 22nd Conference of the Computer-Human Interaction Special Interest Group of Australia on Computer-Human Interaction* (Brisbane, Australia) *(OZCHI '10)*. Association for Computing Machinery, New York, NY, USA, 216–223. https://doi.org/10.1145/1952222.1952269

[5] Andrew Johnston, Shigeki Amitani, and Ernest Edmonds. 2005. Amplifying Reflective Thinking in Musical Performance. In *Proceedings of the 5th Conference on Creativity &; Cognition* (London, United Kingdom) *(C&C '05)*. Association for Computing Machinery, New York, NY, USA, 166–175. https://doi.org/10.1145/1056224.1056248

[6] Yoonji Kim, Youngkyung Choi, Daye Kang, Minkyeong Lee, Tek-Jin Nam, and Andrea Bianchi. 2019. HeyTeddy: Conversational Test-Driven Development for Physical Computing. *Proc. ACM Interact. Mob. Wearable Ubiquitous Technol.* 3, 4, Article 139 (Dec. 2019), 21 pages. https://doi.org/10.1145/3369838

[7] Jarrod Knibbe, Tovi Grossman, and George Fitzmaurice. 2015. Smart Makerspace: An Immersive Instructional Space for Physical Tasks. In *Proceedings of the 2015 International Conference on Interactive Tabletops &; Surfaces* (Madeira, Portugal) *(ITS '15)*. Association for Computing Machinery, New York, NY, USA, 83–92. https://doi.org/10.1145/2817721.2817741

[8] Woojin Lee, Ramkrishna Prasad, Seungwoo Je, Yoonji Kim, Ian Oakley, Daniel Ashbrook, and Andrea Bianchi. 2021. VirtualWire: Supporting Rapid Prototyping with Instant Reconfigurations of Wires in Breadboarded Circuits. In *Proceedings of the Fifteenth International Conference on Tangible, Embedded, and Embodied Interaction* (Salzburg, Austria) *(TEI '21)*. Association for Computing Machinery, New York, NY, USA, Article 4, 12 pages. https://doi.org/10.1145/3430524.3440623

[9] Jennifer Moon. 1999. Reflection in learning & professional development. RoutledgeFalmer, New York, NY, USA. 229 pages.

[10] Donald A Schon. 1983. The reflective practitioner. *How professionals think in action* (1983).

[11] Chiuan Wang, Hsuan-Ming Yeh, Bryan Wang, Te-Yen Wu, Hsin-Ruey Tsai, Rong-Hao Liang, Yi-Ping Hung, and Mike Y. Chen. 2016. CircuitStack: Supporting Rapid Prototyping and Evolution of Electronic Circuits. In *Proceedings of the 29th Annual Symposium on User Interface Software and Technology* (Tokyo, Japan) *(UIST '16)*. Association for Computing Machinery, New York, NY, USA, 687–695. https://doi.org/10.1145/2984511.2984527