The contribution was presented at UAHCI 2017 :
http://2017.hci.international/uahci

To link to this article URL : https://doi.org/10.1007/978-3-319-58706-6_42

To cite this version : Giraud, Stephanie and Truillet, Philippe and Gaildrat, Véronique and Jouffrais, Christophe *"DIY" Prototyping of Teaching Materials for Visually Impaired Children: Usage and Satisfaction of Professionals.* (2017) In: 11th International Conference on Universal Access in Human-Computer Interaction (UAHCI 2017), held as Part of HCI International 2017, 9 July 2017 - 14 July 2017 (Vancouver, Canada).

“DIY” Prototyping of Teaching Materials for Visually Impaired Children: Usage and Satisfaction of Professionals

Stéphanie Giraud[1,2], Philippe Truillet[1,2], Véronique Gaildrat[1,2], and Christophe Jouffrais[1,2,3](✉)

[1] CNRS, IRIT, UMR 5505, Toulouse, France
{stephanie.giraud,christophe.jouffrais}@irit.fr
[2] University of Toulouse, IRIT, UMR 5505, Toulouse, France
[3] CNRS, IPAL, UMI 2955, Singapore, Singapore

Abstract. Professionals working with visually impaired children (i.e. specialist teachers and educators, Orientation and Mobility trainers, psychologists, etc.) have to create their own teaching materials. Indeed, only few adapted materials exist, and do not fully meet their needs. Thus, rapid prototyping tools and methods could help them to design and make materials adapted to teaching to visually impaired students. In this study, we first designed a blog enabling professionals to create their own teaching materials. Then, we set up a challenge with five teams including one professional of visual impairment and students in computer science. The aim of each team was to design and make a teaching material, based on handcrafting, 3D printing tools and cheap micro-controllers, fitting the needs of the professional. After they have used their material with visually impaired students, we interviewed the professionals in order to evaluate usage and satisfaction. The professionals reported that the materials were easy to make, and valuable for teaching to visually impaired students. They also reported that DIY prototyping, based on 3D printing and cheap microcontrollers, enables them to create their own teaching materials, and hence accurately meet unanswered needs. Importantly, they would advise their colleagues to use this method and new tools. However, they consider that they would need assistance to create new materials on their own.

Keywords: Rapid prototyping · Fablab · Visual impairment · Education technology · Blind

1 Introduction

Professionals working with visually impaired students (i.e. specialist teachers and educators, Orientation and Mobility trainers, psychologists, etc.) face many difficulties in the design of their teaching materials. Especially, they have to transpose visual representations and concepts (maps, charts, shapes, etc.) into tactile representations. The most common tools are 2D raised-line maps printed on swell-paper or 3D handcrafted small-scale models (Fig. 1). However, these materials do not fully and adequately meet the needs of both professionals and students. Their production is long and

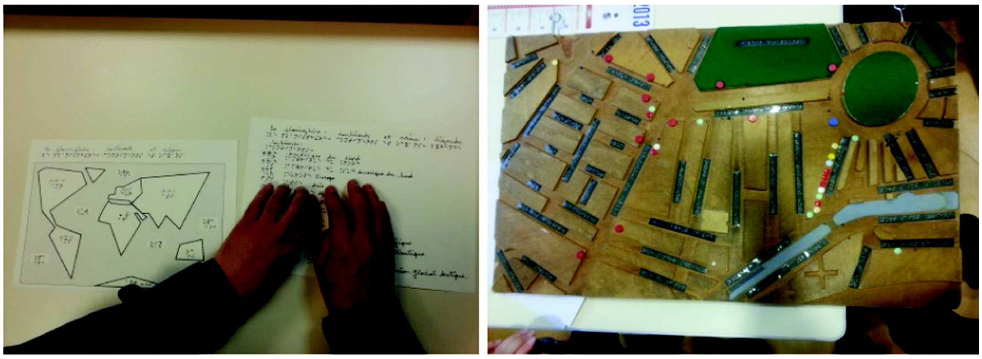

Fig. 1. 2D raised-line map with legend printed on swell-paper (left) and handcrafted small-scale model of a neighborhood (right).

expensive. Moreover, these tools do not allow updating the displayed information, which force professionals to make it again according to the new pedagogical objectives. Finally, they are not interactive, which impairs students' autonomy because they often need someone to provide guidance before or during tactile exploration [1]. With the emergence of new tools for rapid prototyping such as 3D printing and low-cost micro-controllers, making their own teaching materials has become possible [2]. Nevertheless, professionals can be reluctant to use these tools that appear as difficult to master.

In this study, we first designed a blog dedicated to rapid prototyping tools for professionals, aiming to enable the creation of their own teaching materials[1]. Then, we organized collaborative design sessions between professionals and students in computer science. Finally, we set up interviews with the professionals in order to evaluate the usage and level of satisfaction about the materials that were made, but also about rapid prototyping in general.

2 Adapted Teaching Materials: "Do-It-Yourself" (DIY)

With the emergence of 3D printing, new teaching tools are easy to make, such as 3D printed maps [3] or physical representations of graphics adapted for children with visual impairment [4]. Many recent studies have shown that 3D printing really enhances the creation of adapted materials such as globes for geography or biology lessons, geometric shapes for mathematics lessons, or different forms of plankton for biology lessons [5], but also 3D printed tactile books [6], or accessible museum exhibits [7]. Importantly, it has been shown that these materials improve understanding and satisfaction [8], but also engagement of students in Science, Technology, Engineering, and Mathematics [9].

In addition, other recent studies showed that low-cost electronic boards facilitate the construction of interactive physical objects [10]. For instance, these boards improved creative activities with older people [11]. Interestingly, this study

---

[1] http://www.cherchonspourvoir.org/faislepourvoir.

"demystified 'old' stereotypes and opened up a debate about the relationship between wisdom, creativity and technology" [11]. These technologies can also empower children to take greater control of their disabilities [12].

Then, it appears that rapid prototyping tools including 3D printing and cheap micro-controllers may enable professionals to design and make their own adapted materials. However, professionals may be reluctant to use these technologies because they have some prejudices, especially about skills that are needed to use them. Though, Stangl et al. [13] showed that non expert designers of 3D printed adapted objects may benefit from online creativity support tools. For example, the online community "Thingiverse.com" provides many models for assistive tools printing. Buehler et al. [14] highlighted that various models were created by end-users themselves on this platform. Interestingly, these designers do not have any formal training or expertise in the creation of assistive technology. Hurst and colleagues [15, 16] illustrated several examples of materials that can be made by non-engineers. They also observed that it increases the adoption process because it provides end-users with a better control over design and cost. Hence we made the hypothesis that it could be efficient to empower non-experts teachers in order to create, modify, or build their own teaching materials.

Our main objectives were: (1) to assist professionals to create their own adapted teaching materials with rapid prototyping tools such as 3D printing and low-cost micro-controllers, and (2) evaluate the usage of these technologies and the level of satisfaction that they provide.

3 Method

First, we designed a blog dedicated to the professionals who wanted to make their own adapted teaching materials. This blog provided text and video tutorials on how to design and make teaching materials on its own. It also allowed sharing digital files (3D models, audio files, etc.) and tips. Some downloaded files were provided by the research team whereas others were provided by professionals themselves.

Then, we managed sessions of collaborative design, and we launched a challenge about the prototyping of adapted interactive teaching materials. The challenge was based on the constitution of teams including one professional, and 1 to 5 undergraduate students in computer science. Five professionals, including three teachers, one educator, and one tactile document maker, were recruited in a special education center. The professionals were in charge of visually impaired children from three to twenty years old. Some of them presented associated mild or severe auditory impairment, behavioral disorders, or pervasive developmental disorders. Except the educator who has been working in the institute for two years only, the others have been working with visually impaired students for ten to twenty years. All of them were frequent users of computers and smartphones, but they were unexperienced about 3D printers and low-cost micro-controllers. After a preliminary briefing about the objectives, tools, and method of the study, each professional launched his own project with a specific pedagogical objective, as well as the envisioned teaching material prototype.

Fifteen undergraduate students (first year) in computer science were recruited. They were involved in a training considering the university FabLab as a tool for learning by doing. They were split in four groups. Each group of students was free to join any professional to work on his/her prototype. One professional preferred working alone and did not receive assistance from the students. Another teacher worked with the research team because the project was considered as too demanding. The main objective for each group was to design a prototype that was easy to make, cheap, usable, and that fitted the needs of the professional.

In order to make 3D artefacts (e.g. objects or figurines), the teams were free to use 3D printers and laser cutters available in the FabLab, as well as diverse materials such as cardboard, tissue, aluminum, etc. Each group also received a Makey Makey board® (JoyLabz LLC), Touch Board® (Bare Conductive Ltd) or LilyPad® (Arduino) to create prototypes that were interactive. The Makey Makey board® was selected for simplicity of usage; the TouchBoard® because it allows making prototypes without any wire (which is appropriate for visually impaired users); and the Lilypad because it is designed for e-textiles and wearables projects.

The sessions of collaborative design were organized once a week during two hours. During the sessions, each team allocated the tasks to create the prototype: printing 3D artefacts; handcrafting with cardboard, wood, tissue, etc.; writing the code if necessary; and wiring the interactive zones with the micro-controller board. The teams were free to meet whenever they wanted to (especially for printing 3D artefacts, which needed time). A formal meeting was organized every week, and the teams received assistance from the research team when needed.

One group did not succeed in making an usable prototype. Five usable prototypes were designed and have been used in the classrooms (actually some of them are still

Fig. 2. a: Example of a collaborative design session with all the teams; b, c, d: final ceremony showing attendance, prototypes presentation, and following open discussions.

used) with about twenty visually impaired children. A final ceremony was organized in the special education center twelve weeks later. The whole staff of the Institute (about 100 professionals) was invited to attend the ceremony that consisted in the presentation of each project, followed by the election of the preferred one (Fig. 2).

Sixteen weeks after the ceremony, we sent a questionnaire to each of the five professionals. This questionnaire included open questions about the professionals and their work: particulars (occupation, working experience, etc.), overall usage of new technologies (smartphone, computer, etc.), typical usage of teaching materials in the classroom, and regular process for making them when they are not available in the market. In addition, they were open and closed questions about the making process and current usage of their own prototype: skills needed to make it, usage in the classroom, overall feeling about rapid prototyping tools (satisfaction but also reluctance to use these tools) [17].

4 Prototypes of Teaching Materials: Making Issues, Usage and Satisfaction

The collaborations during the project were creative and stimulating, and all the teams except one realized a prototype that was used for teaching.

The *sensory book* (Fig. 3) included touch and sound experiences. It was designed for visually impaired young children with and without associated disorders in order to stimulate their sense of touch. It was made of tissue and printed 3D artefacts (playground slide, merry-go-round, etc.) The book included sensors, wires and a speaker hidden under the tissue, connected to a Touchboard® inserted into a specific page. When one of the sensors was touched, it triggered a sound or verbal description. The story was entitled “Emma and Louis in the park”, and was about two children going to the playground. The main issue for this team was finding a binding system for the book in order to avoid faulty contacts. This issue was solved by printing a 3D binding piece with several housings for the wires. Visually impaired children really enjoyed reading the book. This type of book could nicely fit the needs of parents and family members, but also educators, psychologists, etc.

Fig. 3. The *Sensory Book*, designed for young visually impaired children. It was made with tissue, cardboard, and 3D printed pieces for the figurines and the furniture in the park.

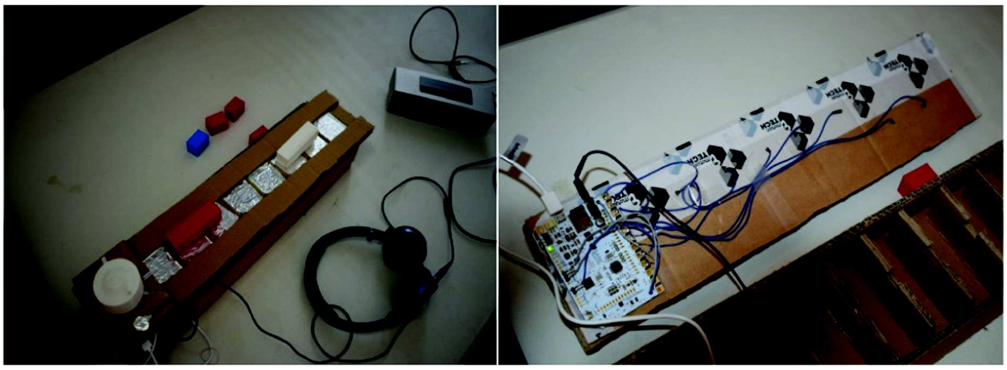

Fig. 4. The *Interactive Timeline*, designed to teach important history periods to high school visually impaired students. It was made of cardboard and aluminum (interactive zones). 3D printed pieces represent the duration of a specific period. The knob was used to modify the level of description for each period.

The *interactive timeline* (Fig. 4) was designed to teach important history periods to high school visually impaired students without associated disorders. It was made with a cardboard box with interactive zones covered with aluminum, and connected to a TouchBoard®. Additional rectangular pieces of various sizes were 3D printed. These pieces were placed over the box in order to indicate a period duration. When touched, the interactive zones triggered verbal descriptions about the corresponding historical periods. A three positions knob placed on the top of the box allowed the students to change the level of description. This knob was the main issue for this team. Indeed, it was difficult to create a knob with three positions that can easily be perceived by visually impaired users. The high school students enjoyed using the prototype. The teacher reported that the interactive timeline was efficient to teach different classes. Importantly, she also mentioned that students were independent when using the timeline and quickly learned to use it. The prototype is still being used.

The *interactive city map* (Fig. 5) was the more complex project, and was made in direct collaboration with the research team. It was designed to teach history and geography lessons to high school visually impaired students without associated disorders. It was made of a wooden box including two TouchBoards®, and 3D printed

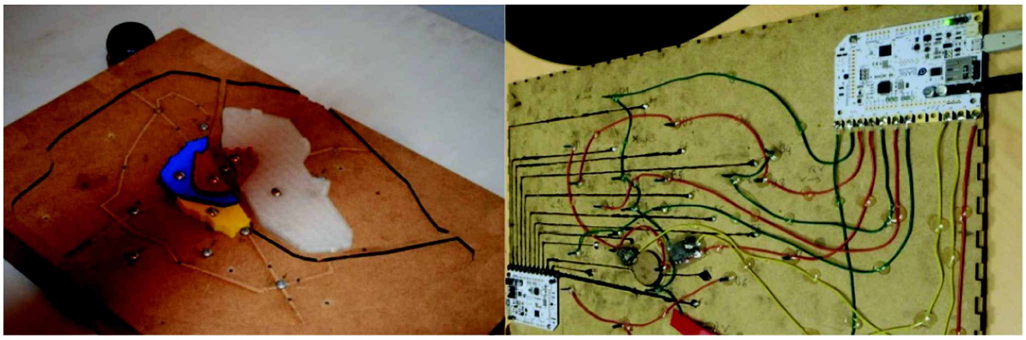

Fig. 5. The *Interactive City Map*, designed to teach history and geography of a large city. It was made of a wooden box and small metallic screws (interactive zones) wired to a Touchboard. 3D removable printed pieces represented the main districts of the city.

pieces representing the main districts of a city. The main landmarks and streets of the city were engraved on the top of the wooden box with a laser cutter. Small metallic screws were inserted in the box, and were connected to the TouchBoards®. The interactive zones triggered verbal descriptions about the name and history of touched elements. The prototype has been designed to serve many years of teaching and is still in used in the classroom. It has been especially used to study the development of a large city. The teacher and the students were really satisfied with the prototype. They reported that it was much more efficient than regular 2D raised-line maps because of the modularity provided by the 3D pieces, as well as interactivity. However, they reported that the interactive zones were too sensitive and should be improved.

The *interactive objects* (Fig. 6) were objects of everyday life (dolls, cutlery, fruits, etc.) connected to a MakeyMakey® board. This project was conducted by an educator without the assistance of any computer science student. It was designed for visually impaired children between five to fifteen years old with important associated disorders, in order to train them to identify everyday objects. Conductive objects were connected to a MakeyMakey® board. When they are touched, they trigger verbal descriptions previously recorded by the teacher. Non-conductive objects were covered with aluminum. In addition, a game was designed by the educator: he was naming objects, and when being touched by the students, the objects themselves provided error or congratulation feedback. The educator was highly satisfied with the device that was easy to make and highly adaptable. She reported that it was easy to teach new vocabulary and she noted a great enhancement in students' concentration and motivation. However, it appeared that the number of inputs onto the micro-controller board was too restrictive.

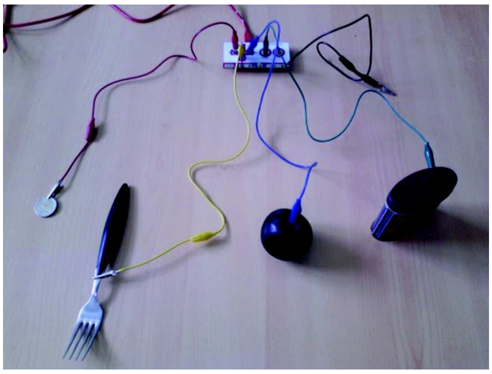

Fig. 6. Interactive *objects,* designed for visually impaired children with associated disorders. Touched objects trigger verbal descriptions previously recorded by the educator.

The *sound metaphor box* (Fig. 7) was designed to teach the notion of size to young visually impaired children with important associated troubles, who need additional motivation to learn. It delivers sound metaphors of objects' dimensions (length, height). This box was a plastic box with small metallic screws connected to a TouchBoard®. They allowed the teacher to choose among different sound-object associations that were previously recorded. The visually impaired children were then free to touch a big knob on top of the box to trigger the sounds. The main making issue was related to faulty contacts. Here again, the teacher observed an improvement of the children motivation. She also noted the pleasure that the children had to play with the box.

Fig. 7. The *sound metaphor box*, designed to teach the notion of size to young visually impaired children with associated disorders. It was made of a plastic box and small metallic screws (interactive zones). The Touchboard is hidden in the box.

In short, the questionnaire showed that the five professionals included in this study have a positive judgement about new technologies in general. Indeed, they reported that they are useful, necessary, efficient, and can adequately meet their needs for teaching a class with visually impaired children. The questionnaire also confirmed that adapted teaching materials are usually missing in the market. The five professionals reported that DIY prototyping was enjoyable, useful and enabling. They were convinced that the method is efficient for creating adapted teaching materials that meet their own needs. They estimated that all their colleagues should use it.

However all the five professionals reported that, although they should be able to remake their own prototype without assistance, they would need additional training in order to create new materials. On the pedagogical side, they enjoyed using the prototypes. They judged that the prototypes materials were usable and adaptable to teach concepts to visually impaired students. They were also convinced that these new materials improve students' motivation. Figure 8 summarizes some of the results.

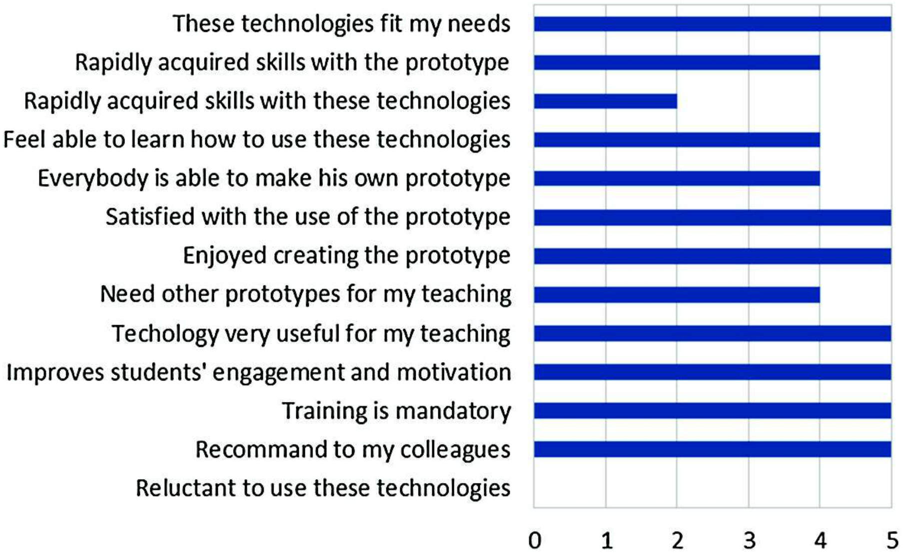

Fig. 8. Selection of questions concerning the prototypes that professionals made, and rapid prototyping technologies in general (N = 5).

5 Conclusion

This study showed that DIY prototyping of teaching materials for visually impaired children is really appropriate and empowering for education professionals. Even though our observations and interviews have been carried out on a small number of participants, the results showed a real potential in special education for visually impaired students. Indeed, the professionals involved in the study designed, made, and used a prototype that meets their own needs. Importantly, one of them made his material alone, relying on the blog support only. They mentioned that low-cost rapid prototyping would better satisfy their needs in general, and would help to improve visually impaired students' engagement and motivation. Overall, the professionals were satisfied and would recommend rapid prototyping to their colleagues.

The professionals wish to make teaching materials on their own because they cannot systematically receive assistance from a technician or a tactile document maker. But it appears that assistance to make it is needed (or appears as needed). In addition, they encountered technical issues during using. Interaction should, in general, be more reliable and prevent unexpected triggering. Besides, the materials should be more resistant to be used by children with cognitive or behavioral disorders. With respect to the complexity of additional teaching scenarios, Raspberry Pi® (Raspberry Pi foundation) or Arduino® (Arduino LLC) may bypass limitations related to the Makey-Makey ou TouchBoard. However, these boards require better expertise.

Acknowledgments. We thank the International Foundation of Applied Disability Research (FIRAH) for financial support and "Cherchons Pour Voir" lab for scientific support. We also thank all the professionals (especially Céline Barbancey, Nathalie Bedouin, Abdelghani Benabdallah, Anne Lorho, and Farida Mesbahi) and children of the Institute of Blind Youth (CESDV-IJA), Toulouse, as well as Julien Berthier, special education teacher with the National Institute of Blind Youth, Paris, for participating in this project.

References

1. Nishimura, T., Doi, K., Masaru, K., Hrioshi, F., Tanaka, Y., Mayumi, S., Susumu, O., Kaneko, T., Kanamori, K.: The creation of in-school tactile guide maps for visually impaired children. In: 36th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (2014)
2. Giraud, S., Jouffrais, C.: Empowering low-vision rehabilitation professionals with "do-it-yourself" methods. In: Miesenberger, K., Bühler, C., Penaz, P. (eds.) ICCHP 2016. LNCS, vol. 9759, pp. 61–68. Springer, Cham (2016). doi:10.1007/978-3-319-41267-2_9
3. Götzelmann, T., Pavkovic, A.: Towards automatically generated tactile detail maps by 3D printers for blind persons. In: Miesenberger, K., Fels, D., Archambault, D., Peňáz, P., Zagler, W. (eds.) ICCHP 2014. LNCS, vol. 8548, pp. 1–7. Springer, Cham (2014). doi:10.1007/978-3-319-08599-9_1
4. Kim, J., Yeh, T.: Toward 3D-printed movable tactile pictures for children al impairments with visual impairments. In: Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems - CHI 2015, pp. 2815–2824 (2015)

5. Teshima, Y., et al.: Three-dimensional models of earth for tactile learning. In: Miesenberger, K., Bühler, C., Penaz, P. (eds.) ICCHP 2016. LNCS, vol. 9759, pp. 116–119. Springer, Cham (2016). doi:10.1007/978-3-319-41267-2_16
6. Stangl, A., Kim, J., Yeh, T.: 3D printed tactile picture books for children with visual impairments. In: Proceedings of the 2014 Conference on Interaction Design and Children - IDC 2014, pp. 321–324 (2014)
7. Salgado, M., Salmi, A.: Ideas for future museums by the visually impaired. In: Proceedings of the Participatory Design Conference, PDC 2006, pp. 105–108 (2006)
8. McDonald, S., Dutterer, J., Abdolrahmani, A., Kane, S.K., Hurst, A.: Tactile aids for visually impaired graphical design education. In: Proceedings of the 16th International ACM SIGACCESS Conference on Computers & Accessibility - ASSETS 2014, pp. 275–276 (2014)
9. Buehler, E., Kane, S.K., Hurst, A.: ABC and 3D: opportunities and obstacles to 3D printing in special education environments. In: Proceedings of the 16th International ACM SIGACCESS Conference on Computers & Accessibility - ASSETS 2014, pp. 107–114 (2014)
10. Silver, J., Rosenbaum, E., Shaw, D., Collective, B., Shaw, D.: Makey Makey : improvising tangible and nature-based user interfaces. In: Proceedings of the Sixth International Conference on Tangible, Embedded and Embodied Interaction - TEI 2012, pp. 367–370 (2012)
11. Rogers, Y., Paay, J., Brereton, M., Vaisutis, K.L., Marsden, G., Vetere, F.: Never too old: engaging retired people inventing the future with MaKey MaKey. In: Proceedings of the 32nd Annual ACM Conference on Human Factors in Computing Systems - CHI 2014, pp. 3913–3922 (2014)
12. Leduc-Mills, B., Dec, J., Schimmel, J.: Evaluating accessibility in fabrication tools for children. In: Proceedings of the 12th International Conference on Interaction Design and Children - IDC 2013, p. 617 (2013)
13. Stangl, A., Hsu, C.-L., Yeh, T.: Transcribing across the senses : community efforts to create 3D printable accessible tactile pictures for young children with visual impairments. In: Proceedings of the 17th International ACM SIGACCESS Conference on Computers & Accessibility, pp. 127–137 (2015)
14. Buehler, E., Branham, S., Ali, A., Chang, J.J., Hofmann, M.K., Hurst, A., Kane, S.K.: Sharing is caring: assistive technology designs on thingiverse. In: Proceedings of CHI 2015, pp. 525–534 (2015)
15. Hurst, A., Tobias, J.: Empowering individuals with do-it-yourself assistive technology. In: Proceedings of ASSETS 2011, p. 11 (2011)
16. Hurst, A., Kane, S.: Making 'making' accessible. In: Proceedings of IDC 2013, p. 635 (2013)
17. Ghiglione, R., Matalon, B.: Les enquêtes sociologiques: théories et pratiques. Armand Colin, Paris (1998)