



Delivering Sensing Technologies for Education and Learning

Andrew Vargo
Osaka Metropolitan University
Sakai, Japan
awv@omu.ac.jp

Victoria Abou-Khalil
ETH Zurich
Zurich, Switzerland
vaboukhalil@ethz.ch

Shoya Ishimaru
German Research Center for Artificial
Intelligence (DFKI)
University of Kaiserslautern
Kaiserslautern, Germany
shoya.ishimaru@dfki.de

Benjamin Tag
University of Melbourne
Parkville, Australia
benjamin.tag@unimelb.edu.au

Mathilde Hutin
LISN-CRNS
Orsay, France

Laurence Devillers
laurence.devillers@lisn.upsaclay.fr
Paris-Sorbonne University,
LISN-CRNS
Paris, France

Andreas Dengel
German Research Center for Artificial
Intelligence (DFKI)
University of Kaiserslautern
Kaiserslautern, Germany
Andreas.Dengel@dfki.de

Koichi Kise
Osaka Metropolitan University
Sakai, Japan
kise@omu.ac.jp

ABSTRACT

Pervasive and ubiquitous sensing technologies have been frequently leveraged in experimental settings within the Ubicomp, ISWC, and HCI community. In the recent past, we have seen advances in the use of ubiquitous sensing technologies to understand and support learning. Recent work investigated a wide range of education-related technologies that detect attention, postures, behaviors, and emotions. However, the promise of delivering these technologies to potential users en masse remains difficult to fulfill. At this time it is important to understand the factors hindering the use of these technologies, to critically evaluate methodologies for technological development, and to discuss in what ways developed technologies can be safely delivered to students. In this workshop, we bring together experts from the fields of ubiquitous and pervasive computing, HCI, and education to discuss and develop an agenda for moving sensing technologies for learning and education from research to practice.

CCS CONCEPTS

• **Human-centered computing** → **Ubiquitous and mobile computing design and evaluation methods**; *Ubiquitous computing*.

KEYWORDS

augmented learning, pervasive computing, physiological sensing for education

Permission to make digital or hard copies of part or all of this work for personal or classroom use is granted without fee provided that copies are not made or distributed for profit or commercial advantage and that copies bear this notice and the full citation on the first page. Copyrights for third-party components of this work must be honored. For all other uses, contact the owner/author(s).

UbiComp/ISWC '22 Adjunct, September 11–15, 2022, Cambridge, United Kingdom

© 2022 Copyright held by the owner/author(s).

ACM ISBN 978-1-4503-9423-9/22/09.

<https://doi.org/10.1145/3544793.3560373>

ACM Reference Format:

Andrew Vargo, Victoria Abou-Khalil, Shoya Ishimaru, Benjamin Tag, Mathilde Hutin, Laurence Devillers, Andreas Dengel, and Koichi Kise. 2022. Delivering Sensing Technologies for Education and Learning. In *Proceedings of the 2022 ACM International Joint Conference on Pervasive and Ubiquitous Computing (UbiComp/ISWC '22 Adjunct), September 11–15, 2022, Cambridge, United Kingdom*. ACM, New York, NY, USA, 4 pages. <https://doi.org/10.1145/3544793.3560373>

1 INTRODUCTION

The Ubiquitous Computing (Ubicomp) community has developed many advances into understanding and furthering sensing technologies that can be used to facilitate human learning activities, both within formal educational settings [1] and in informal learning situations [17]. It is a remarkable feat that we can use sensors to gain insight into a human's behavior and state of mind: physical human activity as well as cognitive human activity. For example, eye-tracking devices can be used to delineate what type of material is being read by a subject [6], sensors can be used to foster creativity within a classroom [12] or digital setting [11], and smart-glasses can infer if the subject is fatigued [13, 14]. Sensors worn on the wrist can indicate whether an individual is confident with their answer to a multiple-choice question [15], and seat-cushions with sensors can infer the attentiveness of a student in a classroom [1]. There are an innumerable amount of ways that sensors and ubiquitous computing can be used to measure human learning activity, but what is currently missing is a bridge to deliver these technologies to individual users and classrooms.

An optimistic viewpoint is that these technologies will eventually be delivered via the marketplace. However, appealing to a sufficient mass of users may not actually have synergy with what is best for all users everywhere. Previous studies have shown that not all augmented learning techniques work for all individuals [4, 15, 17]. Therefore, the application and deliverance of these technologies

must thread the tensions of what is good for classrooms and individual users, while at the same time maintaining the privacy and agency of each user. Such an endeavor requires critical discussion and thinking about how we develop technologies and how they can be delivered to various stakeholders and users. Since sensing for learning often takes place across different modalities, the methods and approaches used can often be redundant and counter intuitive. This workshop will provide a forum for researchers of different modalities to foster and develop new ideas for dissemination.

2 BACKGROUND

Many Ubicomp and Human-Computer Interaction (HCI) research articles focus on learning domains such as language ability through eye-gaze sensing [2, 3, 8], confidence in answering multiple-choice questions [16], attention estimation through pressure sensing [7], detection of reading activities through EOG sensors [5], confidence estimation through keyboard measurements [9], and confidence estimation through handwriting analysis [10]. While all of these technologies are exciting, they have not yet reached mature stages of development where they can reach mass adoption by society or be tailored towards individual users.

2.1 Workshop Objectives

This workshop aims to create an agenda and foster a community for delivering ubiquitous sensing technologies to the wider-world. We will provide a forum for experts to discuss future pathways for research, realistic obstacles for delivering technologies, and methods for robust testing. The specific goals of the workshop are as follows:

- **Activate an Interdisciplinary Community Focused on Disseminating Technology:** Augmenting peoples' learning experiences is still something that is new. Due to the potential impact of sensing implementation, it is important that a community of experts from different fields is brought together to share and discuss the various outcomes and growing pains the technology may bring before it matures. This also requires a careful examination of how the technologies are developed and tested in both laboratory settings as well as in-the-wild settings.
- **Identify Key Challenges that Hinder the Deliverance of Technology:** As with any new technology, identifying and addressing challenges to adoption is difficult. While we seek to hear from practitioners and researchers who have successfully implemented technology, we will also seek to hear from those who have faced setbacks which are not published. We will seek to add the voices of researchers who have tried to have a technology or platform work but have failed and hope to learn from their experiences.

This workshop will be held as a companion workshop for the Learning Cyclotron (LeCycl) Project ¹ within the Tri-lateral AI ² initiative between the Japan Science and Technology Agency (JST), the German Research Federation (DFG), and the French National Research Agency (ANR). The goal of the project is to foster a beneficial

relationship between AI driven supplements and all stakeholders in society, with special focus on supporting parts of society that do not have direct input on how the technologies are implemented and how the policies are created.

3 ORGANIZERS

Andrew Vargo is a research assistant professor in the Graduate School of Informatics at Osaka Metropolitan University. His research focuses on supplements for learning, work, and collaboration through ubiquitous sensing technologies.

Victoria Abou-Khalil is a postdoctoral researcher at the Center for Project-Based Learning at ETH Zurich. She studies the effects of technologies on learning, learning in low-resource settings, and the effectiveness of project-based learning.

Shoya Ishimaru is a junior professor in computer science at the University of Kaiserslautern. He leads the Psybernetics Lab, an interdisciplinary research group investigating human-computer interaction, machine learning, and cognitive psychology toward amplifying human intelligence.

Benjamin Tag is a postdoctoral research fellow at the School of Computing and Information Systems at the University of Melbourne. His research focuses on the conceptualization of digital emotion regulation, the investigation of human cognition using biometric sensors, and psychological test methods.

Mathilde Hutin is a junior researcher at the French Interdisciplinary Laboratory for Digital Sciences LISN of Université Paris-Saclay, a laboratory specialized in human-machine interaction, data sciences, language technologies, computer sciences and energy mechanics. She investigates the linguistic correlations between human-human and human-machine interaction as well as technological support to language learning.

Andreas Dengel is the Executive Director at the German Research Center for Artificial Intelligence (DFKI) in Kaiserslautern and the Head of the Smart Data Knowledge Services Research Department at DFKI, as well as Head Chair for Artificial Intelligence at the Technical University of Kaiserslautern. His main research interests are in the areas of machine learning, pattern recognition, immersive quantified learning, data mining, and semantic technologies.

Laurence Devillers is Professor of computer science applied to humanities and social sciences at Sorbonne University, director of research of "Affective and social dimensions of spoken interactions with (ro)bots and ethical issues" at LISN-CNRS (Paris-Saclay). She is a specialist in machine learning (neural networks, deep learning), automatic speech processing and Human-Machine dialog, and affective computing. She is head of the AI chair: "HUMAN-MACHINE Affective Interaction & Ethics" of the DATAIA Saclay Institute as well as a founding member of the HUB France IA, member of the Global Partnership on AI (GPAI) on the future of work.

¹<https://www.lecycl.org>

²<https://www.jst.go.jp/kisoken/aip/en/program/research/trilateral2020.html>

Koichi Kise is a Professor in the Department of Core Informatics, Graduate School of Informatics, and the director of the Institute of Document Analysis and Knowledge Science (IDAKS) at Osaka Metropolitan University, Japan. He is also the director of Japan Laboratory, German Research Center for AI (DFKI). His major research activities are in the analysis, recognition, and retrieval of documents, images, and activities.

4 PROPOSED LOCATION AND HYBRID FEATURES

We plan to hold a full-day workshop on September 15, 2022 at the Cambridge venue. We also plan to facilitate the full inclusion and involvement of online attendees in the workshop discussion. Hybrid discussion will be conducted with Zoom and Miro whiteboards.

5 PRE-WORKSHOP PLANS

One of the main goals of this workshop is to foster a community that is focused on research and policy making regarding the development and deployment of sensing technologies in education. As such, we encourage the submission of position papers, case-studies, and early-stage research papers that explore the topic area.

In preparation for the workshop, we will distribute a Call for Participation and the submission of position papers, case-studies, and on-going research. A small program committee, consisting of the workshop organizers, will peer-review and curate the submissions. This will ensure a well-balanced and focused workshop. Submissions will be required to be in the acmart single-column style and will have a limit of four pages, including the references. We plan to use Precision Conference (PCS) for managing submissions. Submissions will be planned to be archived as a supplement to the proceedings of the conference. The workshop will be announced on the LeCycl website with its own sub-domain. Additionally, we will circulate the workshop call for participation through the funding agencies' mailing lists and other well-known mailing lists. We will take care to make sure that the call reaches potential participants in the industry and in public policy.

The call for participation will request position papers, case studies, and research papers that are within the following themes:

Optimizing Technologies for Personalized Learning: How can we create and disseminate sensing enabled technologies that are tailored to individual students?

Laboratory vs In-the-Wild: How can studies be developed that better represent real-world usage? Are there meaningful differences between laboratory studies and those conducted in-the-wild? Can the Hawthorne Effect be mitigated with certain strategies? How can user privacy be maintained for different modalities?

Delivering Technologies to the Classroom: How can we integrate the technologies into educational organizations? What are the current barriers? Is there a difference between feedback received from users and outcomes recognized with qualitative and quantitative methods?

Mixing Modalities: How can lessons learned from one modality be ported over to other modalities? Are there universal trends with users and adoption?

Outcomes and Culture: What role does culture play in the development, testing, and implementation of sensing technologies

Time	Activity
9:00–09:30	Introduction of the workshop and ice-breaker
9:30–11:00	Presentation, Session 1
11:00–11:15	Coffee Break and Open discussion
11:15–12:30	Presentation, Session 2
12:30–13:30	Lunch break
13:30–16:00	Action Groups
16:00–16:30	Group Discussion
16:30–16:45	Wrap up and Conclusion

Table 1: Tentative Workshop structure and activities

in learning and education? Are there cultural factors that hinder the delivery of technologies?

Ethics, Regulation, and Privacy: How can we ensure that technologies made for good are actually beneficial to society? What steps need to be taken in order to safeguard user privacy and how does government regulation play into design?

6 WORKSHOP STRUCTURE

We propose a one-day workshop with presentations in the morning and early afternoon, activities in the mid-afternoon, and discussions in the late afternoon. We have provided a detailed tentative schedule in Table 1. In lieu of having a keynote speaker, we plan to spend more time on action groups and active discussion.

6.1 Participants and Presenters

We plan for 15–25 participants to be part of the workshop with a hard cap on 25 participants (excluding the workshop organizers). Participation will be open, meaning that participants are not required to submit a paper and present in order to join the workshop activities. The workshop organizers will select presenters based on the quality of submission and reviews, focusing on creating a balanced slate of topics.

6.2 Presentations

The organizers will publicly call for paper submissions, and all submissions will be single-anonymously peer-reviewed. Accepted papers will be invited for oral presentation at the workshop. We will ask presenters to agree to the recording, archiving, and dissemination of their presentations and question and answer sessions.

6.3 Action Groups

We will create action groups consisting of 4–5 participants. Each action-group will focus on creating an agenda for accomplishing the overall goal of the workshop, presenting both a short-term plan (1–5 years) as well as a long-term plan (5+ years). Each group will develop their plans and solutions and present them to the workshop attendees. We will encourage the use of a visual tool such as Miro. Online participants will use Zoom to form their action groups.

6.4 Group Discussion

Following the Action Group presentations, we will commence a group discussion where differences and similarities between the plans can be examined. Debate and sharing of differences of opinions and viewpoints will be encouraged.

7 POST-WORKSHOP PLANS

The organizers will produce and disseminate a research agenda that fosters an active community that will help shape the future of ubiquitous sensing in education and learning. The organizers plan to summarize the results of the workshop for publication in ACM Interactions to call for a greater awareness of the topic.

In addition, the organizers will document the results of the discussions and activities and make them available to the broader academic community and public by making the repository permanently accessible on the LeCycl website. Outcomes will include the creation of a special interest group focused on creating guidelines and raising awareness of both potential uses and problems.

8 CALL FOR PARTICIPATION

Advances in sensing technologies mean that it is possible to build applications that help learners study more effectively. These advances present potential benefits to both individual learners and the education industry. However, many of these technologies have failed to reach the general public and remain theoretical in their usefulness to society. Therefore, it is vital that we understand and develop a plan for advancing and disseminating these technologies.

The workshop "Delivering Sensing Technologies for Education and Learning" aims to gather a community of specialists from UbiComp, human-computer interaction, and education to explore and develop an action plan around the real potential of developing and disseminating the technology. The workshop will be held on September 11th in Cambridge, UK at UbiComp/ISWC 2022. On-line participants will also be supported. We invite position papers, preliminary research, and case studies that focus on sensing in learning and education, although this is not required for workshop attendance. Submissions are required to be in the single-column acmart format and should be no longer than four pages, references included. The workshop comprises a paper committee that will perform a single-anonymous review, and all accepted papers will be archived as a supplement of the conference proceedings. At least one author of each accepted submission must attend the workshop. All workshop participants, both on-site and online, must register for both the workshop and at least one conference day. The deadline for workshop papers is July 29th AoE.

Further workshop details and the submission link can be found on the workshop homepage: <https://lecycl.org/ubicompiswc22/>.

ACKNOWLEDGMENTS

This work was supported in part by grants from JST Trilateral AI Research (JPMJCR20G3) and JSPS Grants-in-Aid for Scientific Research (20KK0235).

REFERENCES

- [1] Toby Dragon, Ivon Arroyo, Beverly P. Woolf, Winslow Burleson, Rana el Kaliouby, and Hoda Eydgahi. 2008. Viewing Student Affect and Learning through Classroom Observation and Physical Sensors. In *Intelligent Tutoring Systems* (Berlin, Heidelberg, 2008) (*Lecture Notes in Computer Science*), Beverley P. Woolf, Esma Aimeur, Roger Nkambou, and Susanne Lajoie (Eds.). Springer, 29–39. https://doi.org/10.1007/978-3-540-69132-7_8
- [2] Katsuya Fujii and Jun Rekimoto. 2019. Subme: An interactive subtitle system with english skill estimation using eye tracking. In *Proceedings of the 10th Augmented Human International Conference 2019* (2019), 1–9. <https://doi.org/10.1145/3311823.3311865>
- [3] Utpal Garain, Onkar Pandit, Olivier Augereau, Ayano Okoso, and Koichi Kise. 2017. Identification of reader specific difficult words by analyzing eye gaze and document content. In *2017 14th IAPR International Conference on Document Analysis and Recognition (ICDAR)* (2017), Vol. 1. IEEE, 1346–1351. <https://doi.org/10.1109/ICDAR.2017.221>
- [4] Riku Higashimura, Andrew Vargo, Motoi Iwata, and Koichi Kise. 2022. *Helping Mobile Learners Know Unknown Words through their Reading Behavior | Extended Abstracts of the 2022 CHI Conference on Human Factors in Computing Systems*. <https://dl.acm.org/doi/abs/10.1145/3491101.3519620>
- [5] Shoya Ishimaru, Kensuke Hoshika, Kai Kunze, Koichi Kise, and Andreas Dengel. 2017. Towards reading trackers in the wild: detecting reading activities by EOG glasses and deep neural networks. (2017), 704–711. <https://doi.org/10.1145/3123024.3129271>
- [6] Md. Rabiul Islam, Shuji Sakamoto, Yoshihiro Yamada, Andrew W. Vargo, Motoi Iwata, Masakazu Iwamura, and Koichi Kise. 2021. Self-supervised Learning for Reading Activity Classification. (2021). <https://doi.org/10.1145/3478088> Publisher: ACM PUB27 New York, NY, USA.
- [7] Ryosuke Kawamura, Shizuka Shirai, Mehra Aizadeh, Noriko Takemura, and Hajime Nagahara. 2020. Estimation of wakefulness in video-based lectures based on multimodal data fusion. In *Adjunct Proceedings of the 2020 ACM International Joint Conference on Pervasive and Ubiquitous Computing and Proceedings of the 2020 ACM International Symposium on Wearable Computers* (New York, NY, USA, 2020-09-10) (*UbiComp-ISWC '20*). Association for Computing Machinery, 50–53. <https://doi.org/10.1145/3410530.3414386>
- [8] Kai Kunze, Hitoshi Kawaichi, Kazuyo Yoshimura, and Koichi Kise. 2013. Towards inferring language expertise using eye tracking. In *CHI'13 Extended Abstracts on Human Factors in Computing Systems*. 217–222. <https://doi.org/10.1145/2468356.2468396>
- [9] Takanori Maruichi, Olivier Augereau, Motoi Iwata, and Koichi Kise. 2018. Keystrokes Tell You How Confident You Are: An Application to Vocabulary Acquisition. In *Proceedings of the 2018 ACM International Joint Conference and 2018 International Symposium on Pervasive and Ubiquitous Computing and Wearable Computers* (New York, NY, USA, 2018-10-08) (*UbiComp '18*). Association for Computing Machinery, 154–157. <https://doi.org/10.1145/3267305.3267609>
- [10] Takanori Maruichi, Taichi Uragami, Andrew Vargo, and Koichi Kise. 2020. Hand-writing behavior as a self-confidence discriminator. In *Adjunct Proceedings of the 2020 ACM International Joint Conference on Pervasive and Ubiquitous Computing and Proceedings of the 2020 ACM International Symposium on Wearable Computers* (New York, NY, USA, 2020-09-10) (*UbiComp-ISWC '20*). Association for Computing Machinery, 78–81. <https://doi.org/10.1145/3410530.3414383>
- [11] Kasia Muldner and Winslow Burleson. 2015. Utilizing sensor data to model students' creativity in a digital environment. 42 (2015), 127–137. <https://doi.org/10.1016/j.chb.2013.10.060>
- [12] Ivanna Shubina and Atik Kulakli. 2019. Pervasive Learning and Technology Usage for Creativity Development in Education. 14, 1 (2019), 95–109. <https://www.learntechlib.org/p/207161/> Publisher: International Journal of Emerging Technology in Learning.
- [13] Benjamin Tag, Tilman Dingler, Andrew W. Vargo, and Vassilis Kostakos. 2020. Inferring Circadian Rhythms of Cognitive Performance in Everyday Life. 19, 3 (2020), 14–23. <https://doi.org/10.1109/MPRV.2020.2994914> Journal Name: IEEE Pervasive Computing.
- [14] Benjamin Tag, Andrew W. Vargo, Aman Gupta, George Chernyshov, Kai Kunze, and Tilman Dingler. 2019. Continuous Alertness Assessments: Using EOG Glasses to Unobtrusively Monitor Fatigue Levels In-The-Wild. (2019), 1–12. <https://doi.org/10.1145/3290605.3300694>
- [15] Seiya Tanaka, Andrew W. Vargo, Motoi Iwata, and Koichi Kise. 2021. Confidence Estimation via Wrist Movement. In *Adjunct Proceedings of the 2021 ACM International Joint Conference on Pervasive and Ubiquitous Computing and Proceedings of the 2021 ACM International Symposium on Wearable Computers*. Association for Computing Machinery, 76–77. <https://doi.org/10.1145/3460418.3479286>
- [16] Kento Yamada, Koichi Kise, and Olivier Augereau. 2017. Estimation of confidence based on eye gaze: an application to multiple-choice questions. In *Proceedings of the 2017 ACM International Joint Conference on Pervasive and Ubiquitous Computing and Proceedings of the 2017 ACM International Symposium on Wearable Computers* (New York, NY, USA, 2017-09-11) (*UbiComp '17*). Association for Computing Machinery, 217–220. <https://doi.org/10.1145/3123024.3123138>
- [17] Kohei Yamaguchi, Motoi Iwata, Andrew Vargo, and Koichi Kise. 2020. Mobile vocabulometer: a context-based learning mobile application to enhance English vocabulary acquisition. In *Adjunct Proceedings of the 2020 ACM International Joint Conference on Pervasive and Ubiquitous Computing and Proceedings of the 2020 ACM International Symposium on Wearable Computers* (2020). 156–159. <https://doi.org/10.1145/3410530.3414406>