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Learning Cyclotron: An Ecosystem of Knowledge Circulation

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ABSTRACT

The circulation of knowledge is an important function for enriching our social life. Knowledge circulation, which has traditionally been conducted manually, is undergoing a transformation in the age of artificial intelligence. In this paper, we describe our project called “Learning Cyclotron (LeCycl),” which was initiated to accelerate the circulation of knowledge for building a knowledge ecosystem based on artificial intelligence technology. The three functions of sensing, mastering, and transferring knowledge are effectively operated through the power of AI-empowered digital nudging strategies. We outline what has been accomplished to date and summarize future directions for the ultimate goal of LeCycl.

CCS CONCEPTS

• **Human-centered computing** → **Empirical studies in HCI**; • **Applied computing** → **Collaborative learning**.

KEYWORDS

Human learning, Intelligence Augmentation, Knowledge Circulation, Nudge

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1 INTRODUCTION

In the coming age of 100-year life, the conventional three-stage model of “learn, work, retire” will no longer be viable, but a multi-stage model in which learning and working intersect in multiple stages will become a necessity. Under these circumstances, it is necessary to have a mechanism to connect those who have knowledge

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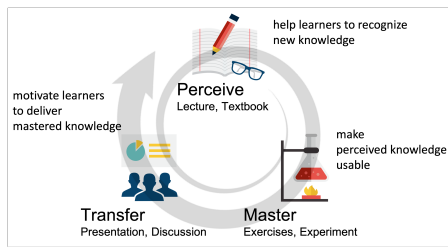


Figure 1: LeCycl Overview.

with those who want it, and to distribute knowledge flexibly and quickly. We call it an ecosystem of knowledge circulation.

Project Learning Cyclotron (LeCycl) aims to build a framework to realize such an ecosystem. This framework is implemented by three functions: *Perceive*, *Master*, and *Transfer*. *Perceive* is a function to know what knowledge is lacking for the learner, *Master* is a function to make the lacking knowledge usable, and *Transfer* is a function to better convey the acquired knowledge to others. In addition, nudge strategies are important to encourage people to participate in the ecosystem.

This paper summarizes the technology currently being developed for LeCycl, which is at the midpoint of the project, and discusses future directions.

2 PROJECT OVERVIEW

Fig. 1 shows the overall picture of LeCycl. The following 3 phases: *Perceive*, *Master*, and *Transfer*, are repeated in LeCycl to circulate knowledge. First, the learner recognizes areas where his or her own knowledge is lacking at the *Perceive* phase. Specifically, the system senses the learner’s behavior and analyzes the sensing results to suggest weak points. Next, the system compensates for the discovered weaknesses to make the learner use the knowledge at the *Master* phase. Concretely, it is achieved through the use of knowledge such as exercises. The degree to which the knowledge is secure is determined based on the learner’s behavior during the exercises and the results of the exercises. The last phase *Transfer* confirms the certainty of one’s own knowledge by transferring the acquired knowledge to others, and also contributes to the circulation of knowledge. This is achieved by matching acquired knowledge with learners who need that knowledge. In practice, not only knowledge matching but also factors such as compatibility between people are taken into account.

In order to make learners perform the three phases, it is necessary to design incentives and a mechanism (nudge strategy) to motivate learners to do so. In this project, we will study what kind of strategies are suitable for these points as well.

Currently, English as a second language and programming are being studied as fields in which the above framework can be evaluated. These subjects are important for Japanese, German, and French undergraduate and graduate students at different levels. Another important aspect of this project is to examine whether there are differences in the functions needed for knowledge circulation (three phases as well as nudge strategies) in different countries.

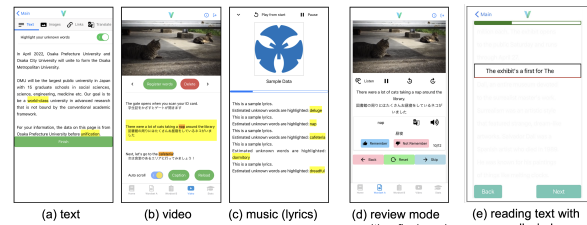


Figure 2: Multimedia Vocabulometer. Text (a), video (b) and music (c) can be used to find unknown words for the learners. The multimedia flashcard (d) can be used for better review. For the case of text, it is possible to estimate unknown words automatically from the reading behavior through the small window.

In the following sections, we summarize the efforts to date in each country for each field.

3 LEARNING ENGLISH

3.1 Text-Based Technologies

3.1.1 *Perceive*. As a way for learning English vocabulary and grammar, we have focused on Multiple Choice Questions (MCQs), and we are developing a method for estimating the confidence in the answers [6]. This enables us to review the cases in which a correct answer is given without confidence, and to draw attention to the cases in which a wrong answer is given with confidence. We have employed a variety of sensors such as eye trackers, key-loggers, pen tablets, wristband accelerometers, and webcams to estimate confidence (For example, [14]).

As a different method for learning English vocabulary, we have taken up flashcards and worked on their multimedia version called multimedia vocabulometer. Specifically, as shown in Fig. 2(a)–(d), word learning using not only text but also video, music, and manga has been realized on smartphones [7, 17]. We are also developing a method for estimating unknown words by using a small window-type interface when reading text on a smartphone (Fig. 2(e)) [5].

3.1.2 *Master*. In general, repeated practice using exercises makes it possible to master the knowledge. If the difficulty level of an exercise is too easy or too difficult, it is often difficult to continue practicing. Conversely, it is desirable that the level of difficulty matches the level of one’s knowledge in order to continue practicing problems. As a fundamental technology for such adaptive question generation, we are working on automatic generation of fill-in-the-blank and four-choice questions.

Automatic generation of a fill-in-the-blank question is a method to automatically select a word that should fill a blank space from a plain sentence without a blank space. We have realized this function by fine-tuning the network to select words that should fill in the blanks, based on a Masked Language Model called RoBERTa.

For automatic generation of 4-choice questions, we realized a method for automatic generation of distractors (wrong choices) based on RoBERTa as well. In general, the difficulty level of 4-choice questions varies depending on the wrong choices. Therefore,

by sorting the distractors in order of difficulty, and selecting appropriate ones based on the difficulty, it is possible to generate 4-choice questions of various difficulty levels.

3.1.3 Nudging Technologies. We are also working on nudging technologies to promote English learning. Here, we present an example of a technology for facilitating individual learning: habit-attached learning assistance. The method we have developed, which we call habit-attachment learning, is a pseudo-habit-forming approach in which micro-learning is attached to the learner’s habitual actions (e.g., browsing the Web or watching YouTube). The content to be learned is automatically selected based on the action the user took immediately before learning. Experimental results show that this system increases learning opportunities compared to simple notification-based learning facilitation.

3.2 Speech-Based Technologies

3.2.1 Perceive. When we think about estimating learners’ cognitive state with speech-based technologies, reading English documents aloud is a good choice. Reading aloud is a manner of learning English that connects vocabulary, the knowledge of grammar, and the knowledge of pronunciation by reading English sentences aloud. In addition to speech, eye gaze can be recorded and used for the estimation of the performance of the speaker while reading aloud [4]. In particular, we focus on two questions.

First, we estimate unknown words based on speech and eye gaze in reading aloud Japanese manga translated into English, where texts are distributed by a speech balloon on a page. This arrangement makes the balloon-wise analysis possible, where each balloon includes a short sentence. We investigate the unknown word estimation for each episode, page, and balloon based on speech and eye gaze features.

Second, we estimate fluency in English as a second language by coupling acoustic analyses of speech with eye-tracking measures [9]. To that extent, participants read a text aloud in front of a computer screen equipped with an eye-tracker. Then the recording of their performance is automatically aligned using WebMAUS, the online open-access aligner from the University of Munich [8, 13]. In a first step, the error-rates of the recognition software, designed for native speech, will be highly informational. In a second step, the revised alignment will allow us to draw conclusions regarding the relationship between English knowledge and pronunciation.

3.2.2 Master with nudge strategies. The combination of acoustic and eye-tracking measures will allow us to propose a device spotting students’ challenges often represented by disfluencies (such as hesitations, pauses, repeating), suggesting uncertainty in their own knowledge or stress levels. An automatic alignment tool will be used to perceive such disfluencies in real time during exercise sessions. In order to extend our learning framework to spontaneous speech, we will use machine learning techniques to also develop an automatic speech recognition (ASR) system. Finally, we hope to develop a model in which the perception of disfluencies by the ASR system triggers the appropriate nudge and help students practice more on the less-mastered points.

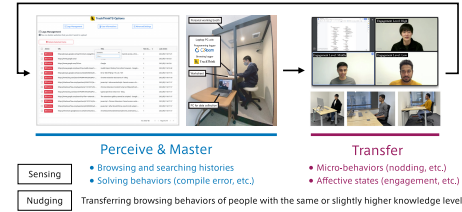


Figure 3: An overview of the proposed platform to teach programming to each other.

4 LEARNING PROGRAMMING

We are developing a platform for learning programming as shown in Fig. 3. The unique aspect of the proposed platform is that a learner acquires knowledge from experts directly or indirectly. Behaviors of learning and teaching are tracked by sensors and are utilized to personalize learning materials. People usually write program code while searching the Web for syntax and library usage. Some programmers write code by following a document, and others try to find working code by using an error message as a search query. Our hypothesis is that following the browsing behavior of someone slightly above the learner and explaining the coding process to others is effective in learning programming.

4.1 Tracking browsing and solving behaviors while programming exercises

As the perceiving and mastering phase, we have focused on the activity of solving programming exercises. In our pilot study, we invited participants to the lab/lecture and asked them to write code on our online system (example: “Define a function $c2f$ that converts Celsius to Fahrenheit in Scheme Language. Note that $f = 1.8c + 32$ ”). Submissions were automatically executed and participants were informed of the results and errors. They were allowed to search the Web during the experiment, and the browsing behaviors were stored by our browser extension [10]. As a result, browsing and solving data from 33 participants have revealed that the level of programming domain knowledge can be classified into two classes with an accuracy of 95 % by utilizing behavior-oriented features and Random Forests.

4.2 Tracking micro-behaviors and affective states while social interactions

Not only indirect transfers (e.g., sharing documents with other learners) but also direct transfers such as teaching are also in our interests. As a starting point, we developed algorithms to detect micro-behaviors in social interaction, including speaking, nodding, and smiling. The proposed algorithms were evaluated in an in-person (offline) and a remote (online) condition [16], and published as software [1]. As an extension of the work, we are also investigating how to estimate the affective states of teachers/learners (e.g., the level of engagement and comprehension).

5 NUDGING STRATEGIES FOR PERCEPTION, MASTER AND KNOWLEDGE TRANSFER

Nudges are a concept established by Thaler and Sunstein [15]. A digital nudge, as any kind of nudge, is an almost imperceptible incentive in the design of a digital system to drive behavior that is supposed to improve personal or collective well-being. Sludges are mostly considered as a particular kind of nudges, which add friction to the decision-making process. At present, digital nudging mechanisms in education are beginning to use familiar online technologies and different strategies such as peer-effect, habits, repetition, etc. From the sensors' signals (vision, speech, eye-tracking), cognitive/affective states including also attention, interest, concentration, mental workload, and self-confidence will be extracted. The estimated states can be utilized to select how to nudge learners. A large literature describes the use of nudging strategies for education [2]. In [12], we presented an experimental protocol during which children from 5 to 10 years interact with a dialog system capable of nudging, i.e. to influence through indirect suggestions which can affect behavior and decision making. We reported on an automatic user states' detection experiment based on paralinguistic and linguistic cues [11] for driving an automatic nudging system that adapts to the user. First results in a Wizard-of-Oz experimental protocol highlighted that the conversational agent and the robot are more influential in nudging children than a human interlocutor.

In the LeCycl Project, nudging strategies can be used for all the steps of the learning phase: perception, master and transfer learning. During the perceiving and mastering phase, nudging mechanisms such as habit-attached learning assistance or bio-feedback enhancement devices can be used to solve exercises. During the Knowledge transfer, we can extract the level of engagement of the learners and give feedback to the teachers in the platform in order to help them modify their strategies. All these strategies will be tested in our virtual environments in our 3 labs in Japan, France and Germany, for instance by measuring whether such nudging information (popup window with informational nudges, assistance or other kind of alerts in the design) actually increases learners' motivation (that could be measured by the duration and regularity of learning sessions on the platform but also by micro-behaviors and affective states automatically detected) and subsequent performance (that could be measured by tests).

All digital nudges using AI mechanisms as statistical inferences from users' behavior, are raising new ethical concerns [3] in particular with children. In fact, these nudges augmented by AI reinforce the ability to achieve the designer goals using cognitive biases, emotional impulses and other human behavioral mechanisms both intentionally (with the informed consent of the user) or unintentionally (caused by automatic inferences of the system). Ethical issues, including in the learning environment, will also be highlighted. For instance, poor experimental designs could result in discrimination, as some nudges may have better effects on some populations than on others.

6 CONCLUSION

We have presented the objective and the current status of our trilateral project "Learning Cyclotron (LeCycl)." The goal of LeCycl is to build a knowledge ecosystem that is supported by AI technologies

to boost circulating knowledge among people. In the project, we focus on two modalities (text and speech) in two fields, learning English as a second language and programming to develop the cyclotron consisting of the three functions *perceiving*, *mastering*, and *transferring*. The digital nudging strategies are one of the key technologies in all three functions, for encouraging learners to perform the functions.

Although we have already obtained some results, many are still ongoing. Till the end of the project, which is in 1.5 years, we would like to complete our missions and show the details of results at a next workshop and/or as papers.

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