Impact Objectives

- Close the gap between the importance of questions and the method of evaluating questions
- Develop a general-purpose question evaluation method and a development method

Advancing question-intelligence

***Professor Fumihito Ikeda**, from the **Institution for the Advancement of Higher Education** at **Hokkaido University** discusses his work using deep neural networks to develop standards to evaluate and test questions in a bid to teach advanced question-intelligence*

Firstly, can you talk about how you became involved in such an interesting research field?

I previously worked for a system integrator and one of the tasks was to improve the in-house helpdesk system, which answered questions from system engineers. However, approximately 30 per cent of the answers were not rated useful and it became my mission to reduce this percentage as much as possible. Asking questions has always been a very important ability. However, although many renowned authors and books domestically and abroad pointed out the importance of asking questions, we do not learn how to ask questions at school, despite learning how to answer them. Japan is a country where university entrance exams strongly influence primary and secondary education, so I thought that if we can evaluate questioning ability in university entrance exams, we can transform Japanese education. I moved to Hokkaido University and have since been working on these topics in relation to university entrance examinations.

Why do you consider questions to be more important than answers?

The answer is defined by the question (problem definition). However, since a question is free in nature, it has more creative value than the answer. Moreover, the act of asking voluntarily cannot be performed by existing Artificial Intelligence (AI) as it is a creative act unique to humans. Also, since the consciousness to give an answer when asked works if it is directed to oneself, it leads to independent learning and if it is directed to others, it can also motivate others. Conversely, once an answer is given, you do not think any further.

How are you hoping to close the gap between the importance of questions and the method of evaluating questions?

Many have pointed out that questions are more important than answers. The method of evaluating questions depends on the context and there is no general evaluation method. This means that there is no general evaluation standard and no established method to develop ways to ask questions. I want to close the gap between the importance of questions and the method of evaluating questions. By bridging this gap and developing a general-purpose question evaluation method and a development method, we believe that education will be fundamentally transformed, and society will become more creative and independent.

Who will benefit from your learnings?

I think the ultimate impact is that children all over the world will learn how to ask questions rather than just learning how to answer them. Researchers from Oxford University (Frey & Osborne, 2017) have hypothesised that in the next five to 15 years, approximately half of current occupations will be replaced by technology. This means that we need to find more creative work that cannot be accomplished by AI. Current AI technology can give answers but has an inability to ask the question spontaneously. This ability is what sets us apart.

In what ways are you involved with education research institutes and academic societies?

In creating test questions that measure question-intelligence, we are working with educational research institutes. These institutions have a wealth of learning content, test question data and development know-how across primary and secondary education. Thus, test questions on question-intelligence can be guaranteed in terms of quality and variety. We expect that development efficiency and ease of deployment in high schools and universities will be a smooth process. Once we have developed a programme to foster question-intelligence, we hope to work with the Japan Society for Science Education and the Japan Creativity Society to implement it in elementary and secondary schools as well as universities. ▶

Asking creative questions

*Researchers at the **Brain Science Research and Education Center** in Japan are developing questioning skills in children during primary and secondary education*

The development of knowledge relies on the ability to ask questions. Indeed, to many researchers, the questions asked are even more important than the answers, and the skill of being able to properly frame and focus on the right questions can make or break a research project. However, while these skills are incredibly important, they are not clearly defined, nor are they taught or evaluated within primary or secondary educational systems.

Professor Fumihito Ikeda, from the Brain Science Research and Education Center/the Institution for the Advancement of Higher Education at Hokkaido University, has been working on the development of evaluation standards and a testing environment for these standards in relation to questioning skills. 'Asking is an expression of curiosity and the beginning of an inquiry,' he says. 'However, in order for the inquiry to be universal and scientific to humankind, the process needs to be logical.' Ikeda argues that this process and the steps in logic behind it should be taught to children at school as the development of critical questioning skills would benefit them as future leaders.

Ikeda tells us that there are three major logics, including inductive reasoning, deductive reasoning and abductive reasoning. 'All of these are inferences but there is a gap between the premise information from which the inference is based and the proposition that is the result of the inference,' he explains. Ikeda and his team are now developing test questions and training programmes for schools that generate questions focusing on these three types of logical reasoning based on how accurately the gap in this logical reasoning can be asked.

THE PROCESS OF DEVELOPMENT

This project, which aims to develop and train primary and high school students in question-intelligence, is centred on using the three types of logical reasoning. These were used to evaluate questioning ability while retaining the creative element of the questions asked. 'We created a test question that critically uses these three types of logical reasoning and tried it on approximately 200 high school students,' says Ikeda. These results suggested that the reliability and validity of test questions can be verified statistically and lent credence to the hypothesis that the inquisitiveness of the students can also be measured using a questionnaire. Ikeda's team also organised the perspectives from which they examined the three types of reasoning before applying a deep neural network (DNN), a form of deep learning, and using the relevant question data for each perspective. This helped in the automatic classification and evaluation of questions being studied.

'To collect more appropriate questions for DNN to learn, an inquiry learning programme that will improve the quality of scientific questions (research questions) while asking different types of logic will be created and it will be implemented in high schools and universities,' Ikeda outlines. He plans to leverage his partnerships with the Japan Society for Science Education and the Japan Creativity Society to roll out these programmes to students at educational institutions.

Ikeda developed a question-intelligence test that evaluates the ability to ask logical reasoning questions based on three types of logical reasoning. 'The first phase of the process of creating scientific questions is to "understand" scientifically-verified knowledge by inductive reasoning,' he explains. However, this knowledge can be distorted or may be missing parts when verbalised. 'Understanding verbalised knowledge means recognising Gestalt, which has a wholeness that is greater than the sum of the parts,' Ikeda observes.

It is also important to recognise the difference between prediction and reality, and identify a way to bridge that gap with hypothetical reasoning. Using hypothetical reasoning to develop questions and to find the best hypothesis to suit the work is vital. This optimum hypothesis then becomes a research question. 'We believe that scientific and creative research questions can be created by thoroughly asking the three logical inferences in the process of creating scientific questions,' states Ikeda.

RESEARCH CHALLENGES

Given the subject matter of his work, Ikeda faced several challenges in framing and implementing his research. The greatest challenge he had to overcome so far was in how to develop evaluation standards for questions. He answered this using logic as the basis of the scientific enquiry process, drawing inspiration from Wittgenstein's work on logical space. Obstacles were also faced in the attempt to develop test questions that challenged question-intelligence. The three types of logical reasoning were not always mutually independent and thus each played a series of roles in the enquiry process. 'It is necessary to ask in the scientific inquiry process of understanding something by inductive reasoning, making some prediction by descriptive reasoning based on that understanding and closing the gap between the prediction and reality by hypothetical reasoning,' explains Ikeda. 'By clarifying such a process, we were able to develop questions that ask each logical reasoning in this process.'

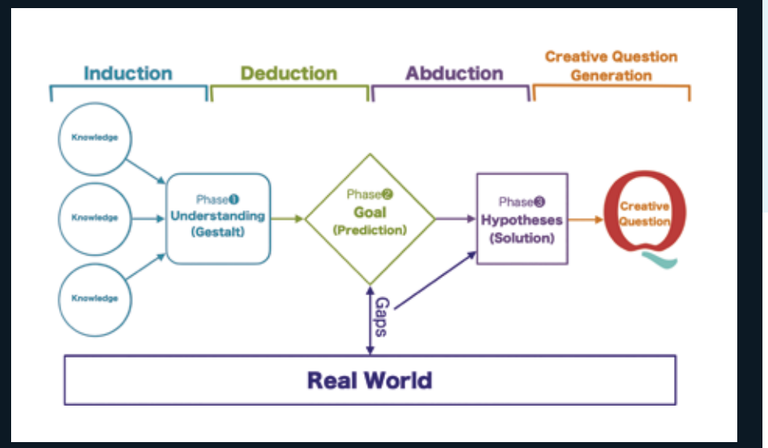
> *"We believe that scientific and creative research questions can be created by thoroughly asking the three logical inferences in the process of creating scientific questions"*

A trial test was conducted using Ikeda's test questions on around 200 high school students. Processing these results proved to be challenging. Although Ikeda was able to statistically show that the test was able to measure the ability of the students to form useful questions or to differentiate curiosity from what is traditionally accepted as academic ability, there were few questions available for this process. Thus, the team was unable to accurately assess how the children were able to properly ask the questions. To tackle this, they developed an educational programme to foster the creation of scientific research questions using the three logical inferences during the scientific enquiry process. Ikeda hopes that expanding this programme throughout schools in Japan can also help in increasing the data available to train the DNN.

DEVELOPING CHILDREN AND SOCIETY

Introducing these ideas into the education system in Japan to teach children creative questioning ahead of their tertiary entrance exams is a priority for this research team. Japanese high schools have introduced a new subject named 'Enquiry' into the curriculum, which covers a loop that begins with task setting and follows on with information gathering, analysis and summary. However, these techniques are not straightforward for secondary school teachers to teach to their students as they usually do not have the research background and thus the familiarity with these methods. Ikeda therefore wants to support more exploratory learning that encourages creativity in thinking than is currently offered. 'The programme allows children to learn the most difficult task setting in teaching exploratory learning in high school, that is, the setting of research questions and implementing a training nationwide to support exploratory learning,' says Ikeda.

It was found that the majority of school-aged children did not understand how to ask questions. Thus, Ikeda believed that it was necessary to develop question-intelligence as a prelude to creating the test measuring question-intelligence. However, it has been vital to collect data from the training programme to feed into the DNN. 'We aim to gather appropriate question data by first setting up a programme that would develop the ability to ask three logical reasoning questions in line with the scientific inquiry process mentioned above and expanding it nationwide,' confirms Ikeda.



Logical Reasoning Model for Generating Creative Questions

Project Insights

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COLLABORATORS
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TEAM MEMBERS
Associate Professors Kazunori Iwama and Naoyuki Iida, Hokkaido University

CONTACT
Professor Fumihito Ikeda

T: +81 11 706 7489
E: fumike@high.hokudai.ac.jp
W: https://inquiry-evaluation.com/

BIO
Professor Fumihito Ikeda graduated from Kyoto University, Faculty of Science in 1994, and completed his MSc in Information Science at the Nara Institute of Science and Technology (NAIST) in 1996. Ikeda then joined NTT DATA Corporation and consequently completed a PhD in Information Science at NAIST in 2001. Since then, he has been based at the Brain Science Research and Education Center, Institution for the Advancement of Higher Education, Hokkaido University.