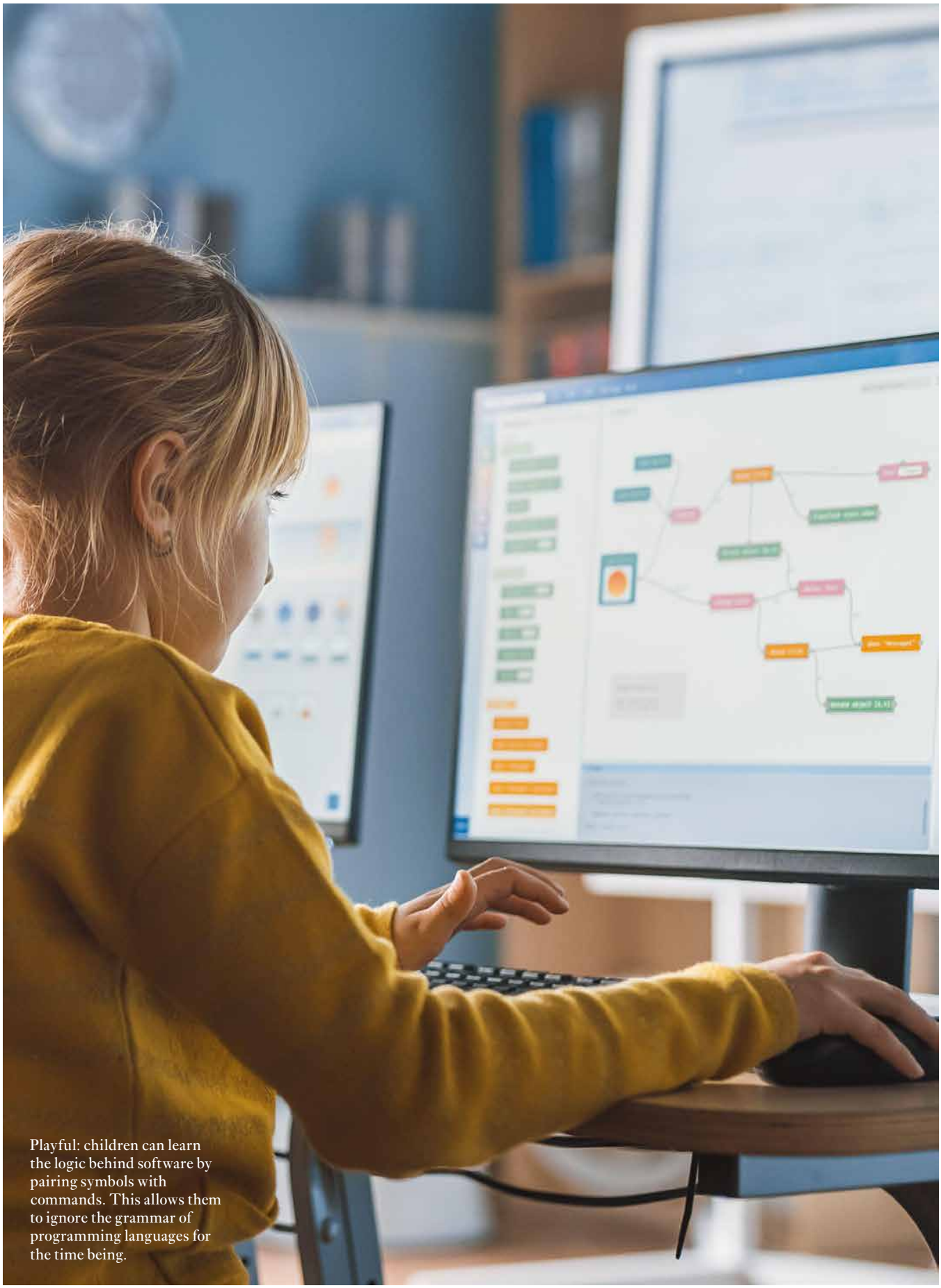

PHOTO: ALEKSEI GORODENKOV / ALAMY STOCK PHOTO

Playful: children can learn the logic behind software by pairing symbols with commands. This allows them to ignore the grammar of programming languages for the time being.

MACHINE TEACHING

TEXT: THOMAS BRANDSTETTER

Artificial intelligence has the power to support people in an ever-increasing number of areas – including education. Researchers at the Max Planck Institute for Software Systems are working under Adish Singla's leadership to find methods to help children learn how to program. These algorithms can, however, also be used in other areas.

Intelligent machines are about to transform society. Not only do they outperform us in chess and Go, but they also translate texts, can assist in making medical diagnoses, and drive our cars. Rather than simply carrying out the commands of their human creators step by step like earlier computer programs, this artificial intelligence learns new skills by analyzing vast amounts of data on its own. In keeping with this concept, the machines are now set to make the step from machine learning to machine teaching and will also be used as intelligent tools in the classroom. This would mean that students could soon be learning how to program machines from the machines themselves.

Beginners usually start out learning programming in a fun way with simple picture elements. Millions of children have already written their first programs in this way through initiatives such as Hour of Code. Researchers at the Max Planck Institute for Software Systems are now going one step further. "We aim to improve children's learning experiences with software that employs artificial intelligence to help learners when they get stuck," says Adish Singla, who is the head of the Machine Teaching group.

Software like this could change school education significantly: "In the classroom of the future, human and digital teachers will work hand in hand," says Maria Wirzberger, professor of teaching and learning with intelligent systems at the University of Stuttgart. However, digital systems can only ever be used to supplement normal classroom activities; they are in no way intended to push human teachers aside. Only humans are capable of truly connecting with students and responding to them intuitively – software is not capable of that. "But software that is designed to provide support can help cover the times when the teacher can't be present," Wirzberger says. For instance, the digital assistant would be able to pitch in during periods of self-directed learning and distribute tasks to learners that are tailored to their needs. It's unlikely that a single teacher would be able to prepare twenty different worksheets for twenty students. "An AI-based system is able to do this very well based on the children's ability profiles," explains Wirzberger. But humans should stay in charge and intervene when specific problems arise. Ultimately, this frees up more resources for providing individual support – both for the weaker students and for the particularly talented ones who can be set extra tasks by the software.

The president of the German Teachers' Association, Heinz-Peter Meidinger, holds a similar opinion. "It all depends on the teacher," he stresses. The teacher is the greatest source of motivation for the students. In a society that is, or will be, increasingly shaped by digitalization and AI, it is also extremely important that these topics are also addressed in schools. "This is both in terms of a teaching subject in which the effects are explored but also as a teaching medium," Meidinger says. Nevertheless, he does not see artificial intelligence as the ultimate solution to all the current problems of the school system, such

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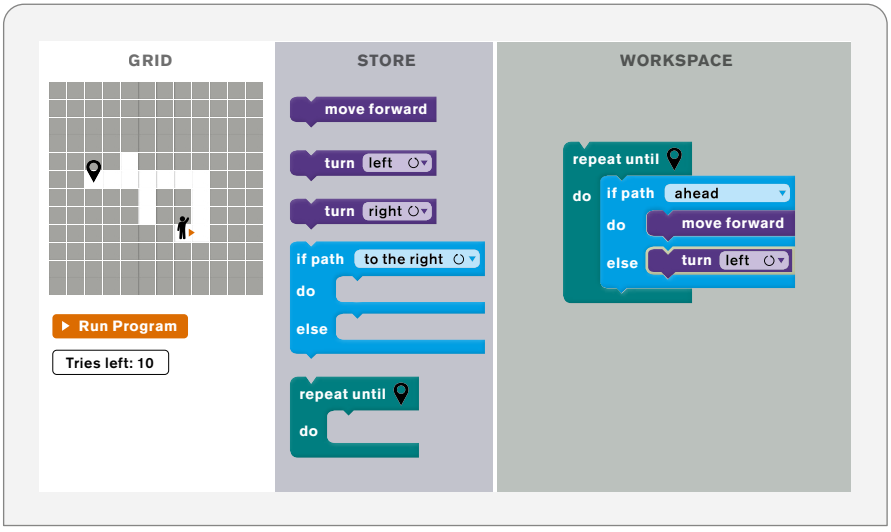
as the shortage of teachers, educational injustice, inclusion, and integration. "In my experience, piling too much expectation onto such new developments always ultimately leads to disappointment."

Meidinger also sees potential for AI in the classroom primarily based on its ability to adapt the difficulty of tasks to the learners' needs. However, he believed that it is also important to realize that this will lead students to different levels of proficiency. "I am very supportive of personalized support for talent, and AI could provide an opportunity to take particularly gifted students deeper into subject areas than has been possible to date," Meidinger says. "At the same time, however, there will also be those who, despite artificial intelligence, will have a much lower level of progress." Ultimately, individual support also always leads to a greater range of abilities. "At the end of the day, we still have a school system that operates based on grades, qualifications, and graduation certificates," Meidinger points out. "So it has to be incorporated appropriately."



GRAPHIC: GCO ACCORDING TO WWW.TEACHING-BLOCKS-HINTS.CC

Block programming: in this task from the Hour of Code initiative, students must correctly string together commands to guide a figure along the white path to a destination. If they encounter difficulties in doing so, a program from the Max Planck Institute for Software Systems provides them with tips and presents them with further tasks tailored to their comprehension needs.

SUMMARY

Algorithms can be used in programming classes to create tasks tailored to individual learners and help them find solutions. This involves setting sub-tasks that specifically aim to improve students' understanding of the steps they are struggling with.

The approach can also be extended to other subjects, such as mathematics, where open-ended conceptual problems need to be solved.

The software will be able to support teachers, but not replace them. Teachers will continue to be the main motivators and will need to intervene in particularly difficult cases. Machine learning methods will, however, provide them with more time to provide individual support.

AI holds a virtual tutorial

Learning to program is particularly well suited to the use of AI in the classroom. One typical exercise for young beginners involves guiding a figure on the screen along a specific path to a destination. This requires precise instructions on how far the figure should move straight ahead on the chessboard pattern behind it, for example, and which direction it should then take. Educators prefer to use block-based, visual programming techniques to introduce children to problems like this. This saves beginners the trouble and frustration that difficult-to-understand written commands and subtleties in syntax (such as the difference between square brackets and curly brackets) can cause. Instead, the children arrange predefined blocks that have short instructions and pictures in a row, enabling them to intuitively instruct the figure to do what they want it to. A typical example of this would be an instruction to keep taking a step forward as long as the path continues in that direction. If the path eventually turns left or right, then another command is required. This allows children to focus their full attention on the logic underpinning the problem and playfully develop an approach to computer-based thinking.

Adish Singla and his team in the "Machine Teaching" research group at the Max Planck Institute for Software Systems in Saarbrücken are continuing to develop exercises like this with artificial intelligence. In 2020, the researchers presented an algorithm that automatically generates exercise tasks using machine learning methods. "Once a student has solved a problem and moved the figure to the target location, we give them another, similar task that they can then use to reinforce what they've learned," says Adish Singla.

Singla's research team is meanwhile working on an AI-powered virtual tutoring system that will also provide children with direct help in solving a particular task. The system will recognize that a student is struggling with the task and try to help them by providing hints. The earlier version of the software simply corrects errors, presenting the correct solution right away, so that the student can continue

working from that point. That is already a great help when it is needed – but it can be even better.

"What we're working on today is much more advanced," says Singla. "The software now helps children with personalized multiple-choice quizzes when they get stuck." In other words, the algorithm develops a small subtask on its own and offers several possible solutions to the problem in order to help the learner get up to speed. It's as if the artificial intelligence were to say, "Think a bit more about this part!" which prompts the child to take action themselves and stay in control. "This is much more motivating than simply fixing a mistake," explains Adish Singla. The challenge for the software, however, lies in being able to identify the simplest task that will allow the child to understand the concept that is causing them difficulty.

Everyone can evaluate the software

"It's not easy to automatically create an appropriate quiz," Singla says. After all, he says, that is a small programming task of its own. While there is theoretically a multitude of possibilities for developing a sub-task like this, only a few of them also have meaningful, interesting solutions that can be used to clarify the unclear programming concept. "One key aspect of our current work is to be able to automatically figure out which misconception underlies the mistake," Singla says. This is the only way the software will be able to help learners correct their misconceptions on their own. Singla and his team are focusing their work on the underlying functionalities of the software. By incorporating AI, they want to make it possible for students to work with it even when no one is around to help them.

Although they are limiting their current work to programming instruction, the methods being developed by the researchers can be applied more broadly, for example, in mathematics. "Essentially, we are trying to develop AI that can help students solve open-ended conceptual problems," Singla says. After all, he says, it is particularly challenging for both the learners and the artificial intelligence when there is no predetermined approach to solving a task. "It's also important for the software to motivate learners and keep them engaged," says Maria Wirzberger. Small, human-like figures that provide clues or important feedback can help with this. "Playful elements can also provide motivation, such as when mathematical puzzles have to be solved in order to find treasure," says Wirzberger. Only when all these aspects come together can a piece of educational software be successful.

The German Teachers' Association, however, would like to see empirical research support the use of AI-supported learning software in Germany, for example, by testing the new methods in model schools. "In the end, the only thing that counts is improving children's education and learning success," says President Heinz-Peter Meidinger. And if it works well, the new technology should then of course be used across the board. Such an approach reflects the spirit of the researchers. That's why Adish Singla's team is already releasing the software online so that everyone can try it out and help evaluate it. This way, the machine assistants will be gradually prepared for their use in the classroom. ***www.teaching-blocks-hints.cc***

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Georgios Tzannetos, Adish Singla, and Ahana Ghosh (from left) discussing how they can enhance the software that supports students by using artificial intelligence.

PHOTO: MATS KARLSSON FOR MPG