Blackbox Challenge in Software Teaching and Learning

Anand Jeyaraj[1,*], Vikram Sethi[2]

Wright State University, 3640 Colonel Glenn Hwy, Dayton, OH 45435, USA
[1]*anand.jeyaraj@wright.edu* *; [2] *vikram.sethi@wright.edu*
**corresponding author*

ARTICLE INFO

Article history
Received May 22, 2023
Revised Dec 15, 2023
Accepted Dec 19, 2023

Keywords
Artificial Intelligence
Blackbox challenge
Teaching
Learning

ABSTRACT

The rapid proliferation and integration of artificial intelligence (AI) capabilities within information systems (IS) tools have significantly reshaped how individuals approach and perform tasks. This evolution necessitates a critical examination of the emerging *"black box challenge"* a phenomenon in which the internal mechanisms and complexities of AI-driven functionalities are obscured from users, even as these tools facilitate efficient task completion. One salient characteristic of many AI-powered tools such as pattern recognition contributes to this opacity by abstracting away cognitive processes traditionally required for problem-solving. For instance, Microsoft Excel's *Flash Fill* feature exemplifies how students can rapidly achieve accurate outputs without necessarily engaging with underlying logic or methodological reasoning. While such tools undoubtedly offer productivity gains, their widespread use may unintentionally diminish opportunities for learners to develop essential cognitive competencies. Consequently, the reliance on AI-driven automation in educational contexts raises profound pedagogical concerns. Over time, the erosion of critical thinking, problem-solving abilities, and metacognitive engagement may compromise not only individual intellectual growth but also the broader societal capacity for innovation and informed decision-making. Thus, the unchecked normalization of such technologies in learning environments may inadvertently undercut the very foundations of lifelong learning and democratic vitality.

I. Introduction

Artificial intelligence (AI) has transformed various information systems (IS) with powerful capabilities that provide significant advantages to users. From basic pattern matching to generative natural language capabilities, AI capabilities have been adopted in IS across various industries. These include expert systems, machine learning, deep learning, robotics, natural language processing, computer vision, and speech recognition applications that have gained considerable acceptance among various user groups [1] AI tools have been incorporated into productivity software tools like Microsoft Office and popular software environments like GitHub. Microsoft Copilot, designed as a conversational chatbot interface, helps users accomplish various tasks such as searching for information, generating summaries of documents, and creating images [2]. GitHub Copilot, designed as a code generator, allows users to engage in software development activities more productively [3], [4].

It is unclear if AI tools (including AI capabilities infused into software tools) are always desirable. AI tools may offer productivity, which could be coveted in work settings where workers are expected to complete tasks and quickly reach goals efficiently. However, AI tools could prove problematic and restrictive in learning environments where productivity may not necessarily be the focus or the desired outcome. Specifically, AI tools may present the "black box challenge" in that the complexity of the task and the steps needed to complete the task may be hidden from learners, and it may not be necessary for them to exercise their intellectual ability or engage in critical thinking and problem-solving activities. While these may yield short-term gains with easy solutions and fast completion times, the long-term effects on society could be damaging. Learners may not experience intellectual growth, assimilate and apply knowledge in different contexts, or develop essential critical thinking and problem-solving skills necessary for excellence.

This paper illustrates the black box challenge imposed by AI tools using a data-handling activity that can be completed in Microsoft Excel and highlights how AI tools may challenge traditional teaching and learning notions. The remainder of the paper is organized as follows. The next section presents an overview of conventional education and learning and its general goals. The subsequent section illustrates the black box challenge that may be experienced in learning environments that use AI tools. The discussion section reflects how traditional teaching and learning may need to be reimagined for the long term. The paper ends with a conclusion section with a call for introspection of teaching and learning methods and mindful use of AI tools and capabilities.

The rapid development of artificial intelligence (AI) technology has brought about significant transformations in the design and use of software, particularly in the context of information systems (IS) and educational environments. The increasing integration of AI features into productivity software has created a new dynamic in the learning experience, where efficiency is often achieved at the expense of deep cognitive engagement. In the context of software learning, particularly in courses that teach basic data manipulation and programming, this phenomenon raises a challenge known as the black box challenge. In this condition, computational processes are hidden behind a user-friendly interface, obscuring students' conceptual understanding of the underlying mechanisms behind a task. In response to this phenomenon, this study presents an empirical exploration using the Flash Fill feature in Microsoft Excel as a case study to highlight how AI enables instantaneous task achievement without engaging in algorithmic problem solving or reasoning. The methods section outlines a learning scenario used in teaching a business analytics class, while the results section illustrates the differences between traditional formula-based and AI-based approaches. The discussion section then evaluates the implications of using AI for the development of students' critical thinking skills and long-term learning. It considers pedagogical strategies that can be designed to address this challenge constructively.

II. Discussion and Solution

A. Traditional Teaching and Learning

Several approaches to teaching and learning are evident in modern classrooms. These include instructor-led or instructor-centered approaches that focus on the instructor delivering the knowledge to students and student-centered or learner-centered approaches that focus on guiding or facilitating students' acquisition of knowledge [5], [6], [7]. Different perspectives, such as experiential learning, active learning, collaborative and/or cooperative learning, and transformative learning, have been applied within these broader approaches [8], [9], [10], [11], [12].

Although subtle differences between different learning perspectives exist, a significant goal is to move away from traditional instructor-centered approaches to student-centered approaches that may facilitate student engagement in learning to a greater extent [7]. While instructor-centered approaches may rely considerably on lectures and assignments, student-centered approaches may use other methods such as games (e.g., crossword puzzles, jeopardy, debates, role play), multimedia (e.g., audio, video), and collaboration (e.g., pair programming, crowd polling, origami) to increase student engagement and learning [7], [13], [14], [15], [16], [17], [18], [19]. These student-centered methods replace in-class lectures with creative problem-solving, critical thinking, and collaborative activities.

Regardless of the specific approaches, the teaching and learning activities typically focus on helping students engage in learning, gain and assimilate knowledge, and develop problem-solving and critical thinking skills [20]. The teaching activities may be instrumental in enabling lifelong learning, which is particularly relevant for students as they are immersed in their professional settings that require constant adaptations due to technological innovations [21], [22] Further, teaching activities facilitate the transfer of knowledge and skills from instructional settings to other general settings, allowing students to extend learning application [23].

B. The Blackbox Challenge

The black box challenge is illustrated using an example in Microsoft Excel undertaken by undergraduate business students in an introductory business analytics course at a large university in the midwestern United States. The course introduces students to various principles and techniques related to sourcing, preparation, analysis, visualization, and interpretation of data for business decision-making. During the course, students gain hands-on learning experience in Excel, Access, Python, and SPSS to accomplish different tasks.

Fig. 1 depicts a continuum that can be used to distinguish between traditional learning (which was the norm before the advent of AI tools) and black box learning (which has become more prevalent since the advent of AI tools). One of the data preparation activities requires students to transform compound data columns into atomic data columns in Excel. For instance, the name field can be split into first name, middle initial, and last name format, or the address field can be divided into street, city, state, and zip code columns, standard in the United States environment. A traditional way of breaking the data into multiple columns is to use a combination of text manipulation functions such as LEFT, MID, and RIGHT available in Excel, which also requires students to identify patterns based on delimiters such as comma or space symbols and possibly use functions such as FIND to locate the positions of the delimiters. This approach also allows exploring other related functions, such as LEN, to determine the number of characters.

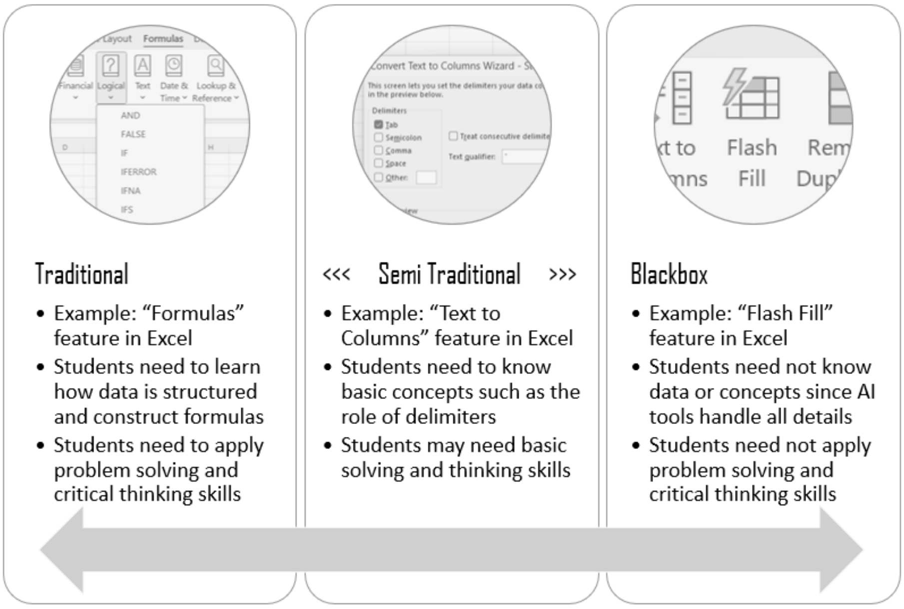

Fig. 1. Traditional vs. Blackbox learning

The formulas to split the street, city, state, and zip codes based on delimiters (assuming the data is organized as an Excel table) include:

```
comma1 =FIND(",",[@address])
comma2 =FIND(",",[@address],[@Comma1]+1)
street =LEFT([@address],[@Comma1]-1)
city =MID([@address],[@Comma1]+2,[@Comma2]-[@Comma1]-2)
state =MID([@address],[@Comma2]+2,2)
zip =RIGHT([@address],5)
```

This method is preferred since it enables students to learn patterns and rules to transfer the learning to other settings as needed. For instance, the same data splitting problem can be handled in Python. Assuming that the address column is loaded in a Pandas dataframe, the street, city, state, and zip code columns may be extracted using the code:

```
addresses = df['address'].values.tolist()
streets = list(map(lambda x: x[:x.find(',')], addresses))
citys = list(map(lambda x: x[x.find(',')+2:x.rfind(',')], addresses))
states = list(map(lambda x: x[x.rfind(',')+2:x.rfind(',')+4], addresses))
zips = list(map(lambda x: x[-5:], addresses))
```

Such knowledge transfer across different environments is beneficial for students since they will not have to rely on specific capabilities of software tools, but focus on implementing their problem-solving abilities as necessary.

However, Excel also includes the "Text to Columns" feature that can be used for similar outcomes. Students will not need to use the formulas introduced above. Still, they can split the data using knowledge of delimiters and select the relevant option from the list of delimiters provided. They can also follow the visual guide of the vertical dividers that show the data will be reorganized consistent with the chosen delimiters.

For the same address column shown earlier, the "Text to Columns" feature can be used twice; first to split the address field based on the comma delimiter and then to split the combined state and zip code column based on the space delimiter. This method moves closer to the black box challenge since students do not need to apply principles related to splitting by patterns. However, they still need to understand delimiters being the basis for splitting combined data into different columns.

Even more pertinent to the black box challenge is the "Flash Fill" capability in Excel, which uses principles of pattern matching and AI. For the same data splitting problem, this feature merely requires students to show a few examples of expected results for the state, city, state, and zip code columns. The "Flash Fill" feature then extracts the results for the four columns from the address column based on patterns.

The "Flash Fill" feature in Microsoft Excel effectively conceals the underlying computational logic required to perform split operations, thereby obviating the need for users, particularly students, to engage with foundational concepts such as string manipulation, pattern recognition, and algorithmic thinking. This abstraction not only diminishes the perceived value of mastering such skills but also disincentivizes learners from exercising analytical reasoning or cultivating problem-solving competencies. Consequently, the black box challenge emerges: a pedagogical dilemma wherein learners, faced with highly accessible AI-enhanced functionalities, may increasingly defer to automated processes in lieu of developing the intellectual resilience necessary for tackling complex, structured problems. In such contexts, the ease of tooldriven task completion risks displacing deeper cognitive engagement, ultimately undermining the cultivation of critical-thinking abilities essential for adaptive expertise and lifelong learning.

While this discussion is not an indictment of the advanced capabilities infused into modern software tools, it does raise awareness of the potential pitfalls in adopting such capabilities while sidelining learning related to fundamentals and principles. This concern resonates with Wing's advocacy for computational thinking, which emphasizes the importance of pattern recognition, abstraction, and algorithmic reasoning as core skills in problem solving [24] In multiple course offerings, several students consulted with the instructor about whether the "Flash Fill" capability could satisfy the assignment requirements, rather than methods that required them to identify patterns and develop strategies to solve the problem. As Binkley et al. have noted, the ability to engage in critical thinking and sustained learning processes is essential in preparing learners for the demands of the 21st century [25]. Without adequate emphasis on foundational learning, overreliance on automation tools may lead to cognitive offloading and a decline in problem-solving resilience [26], [27]

C. Rethinking Teaching and Learning

The foregoing illustration of the black box challenge raises several questions for both teaching and learning. From a learner perspective, students may relish and use the AI capabilities built into software tools to quickly find solutions without spending much effort thinking through overall strategies or steps to solve problems. The use of productivity-enhancing AI tools may be desirable in intensive task environments in work settings, but students may find it detrimental in their learning processes. The overall gains in using AI tools that may be realizable could be significantly diminished if such use comes at the expense of learning opportunities and knowledge growth in individuals. While they may be able to satisfy immediate requirements, students may find their lifelong learning skills and abilities severely curtailed in the long run when extensively relying on AI tools and their capabilities.

The possibility remains that the AI tools may not produce the results desired by students. For instance, in an example to split an individual's full name into first name, middle initial, and last name, the "Flash Fill" capability in Microsoft Excel did not produce the correct results for the middle initial. However, the first name and last name were correctly identified. In such a scenario, when AI tools may not adequately satisfy task needs, students will have to fall back on their skills and knowledge actively. Of course, students can consult reference materials that may allow them to solve the problem and identify potential solutions. However, if students have not taken the time to bolster their knowledge and skills actively but rely on AI tools extensively, they may not be able to solve the problem.

From a teacher's perspective, developing interventions for student learning and engagement with critical-thinking and problem-solving activities becomes challenging when AI capabilities in software tools are widely available and easily accessible. One challenge is related to identifying the content of the learning activities. Rather than simply developing learning interventions that help learn problem-solving and critical-thinking activities, perhaps instructors need to include activities that highlight how knowledge and learning can be transferred to other settings (e.g., applying those principles learnt in the context of Excel to another environment such as Python as described above) or how reliance on AI tools may not always be sufficient or helpful (e.g., showing the errors that are possible as described above).

Instructors may need to motivate students to build lifelong learning capabilities when students may be interested in taking advantage of AI tools and capabilities. The increasing availability of AI-driven features in common software, such as Microsoft Excel, has enabled students to independently discover and apply these tools in academic tasks, often without engaging with the underlying concepts or problem-solving strategies taught in class. This trend reflects a growing reliance on technological convenience, potentially undermining critical-thinking development [28]. As noted by Luckin et al., while AI can enhance personalized learning experiences, it must be accompanied by pedagogical frameworks that emphasize metacognition and lifelong learning skills [29]. Moreover, Selwyn highlights that the allure of AI efficiency can lead students to question the relevance of traditional learning approaches, posing a challenge for educators to strike a balance between leveraging AI tools and nurturing deep cognitive engagement [30].

III. Conclusion

The availability of AI tools and capabilities has raised challenges for traditional teaching and learning since they allow students to bypass problem-solving and critical-thinking requirements to complete tasks. While productivity enhancements possible due to AI capabilities are helpful under certain conditions, exclusive or excessive reliance on such capabilities may undermine individuals' intellectual growth and well-being (first as students and then as professionals) within society in the long run. Traditional teaching and learning methods must be adapted to incorporate motivational and comparative elements such that students will be equipped with problem-solving, critical-thinking, and lifelong learning abilities to influence and shape society. This study raises several directions for future research and practice. First, academia may strive to define what constitutes "learning" in the context of higher education when dealing with AI tools. Second, experiments could be conducted to assess how much reliance on AI tools impacts student learning.

Finally, teachers may design creative learning modules and interventions that encourage students to engage in problem-solving and critical thinking even when AI tools are accessible.

References

[1] C. Collins, D. Dennehy, K. Conboy, and P. Mikalef, "Artificial intelligence in information systems research: A systematic literature review and research agenda," *Int J Inf Manage*, vol. 60, p. 102383, 2021, doi: https://doi.org/10.1016/j.ijinfomgt.2021.102383,2021.

[2] J. Koskula, "Generative Artificial Intelligence in support of analytics: Copilot 365," 2024.

[3] C. Bird *et al.*, "Taking Flight with Copilot: Early insights and opportunities of AI-powered pair-programming tools," *Queue*, vol. 20, no. 6, pp. 35–57, 2022.

[4] J. Prather *et al.*, "'It's weird that it knows what i want': Usability and interactions with copilot for novice programmers," *ACM transactions on computer-human interaction*, vol. 31, no. 1, pp. 1–31, 2023.

[5] G. Griffiths, B. J. Oates, and M. Lockyer, "Evolving a Facilitation Process towards Student Centred Learning: A Case Study in Computing.," *Journal of Information Systems Education*, vol. 18, no. 4, 2007.

[6] B. M. Saulnier, J. P. Landry, H. E. Longenecker Jr, and T. A. Wagner, "From teaching to learning: Learner-centered teaching and assessment in information systems education," *Journal of Information Systems Education*, vol. 19, no. 2, pp. 169–174, 2008.

[7] X. Zhang, C. Zhang, T. F. Stafford, and P. Zhang, "Teaching introductory programming to IS students: The impact of teaching approaches on learning performance," *Journal of Information Systems Education*, vol. 24, no. 2, pp. 147–155, 2013.

[8] C. C. Bonwell and J. A. Eison, *Active learning: Creating excitement in the classroom. 1991 ASHE-ERIC higher education reports.* ERIC, 1991.

[9] J. Cooper and R. Mueck, "Student involvement in learning: Cooperative learning and college instruction," *J Excell Coll Teach*, vol. 1, no. 1, 1990.

[10] P. Dillenbourg, "What do you mean by collaborative learning?," *Collaborative-learning: Cognitive and computational approaches.*, pp. 1–19, 1999.

[11] D. A. Kolb, *Experiential learning: Experience as the source of learning and development*. FT press, 2014.

[12] J. Mezirow, "An overview on transformative learning," *Lifelong learning*, pp. 40–54, 2008.

[13] A. P. Massey, S. A. Brown, and J. D. Johnston, "It's all fun and games... until students learn," *Journal of Information Systems Education*, vol. 16, no. 1, p. 9, 2005.

[14] E. McKinney Jr, B. Niese, and M. S. Bhatia, "Teaching Tip: Active Learning in the IS Classroom: A Student Crowdpolling Exercise for IS Courses," *Journal of Information Systems Education*, vol. 34, no. 2, pp. 118–130, 2023.

[15] M. Mitri, C. Cole, and L. Atkins, "A systems analysis role-play exercise and assignment," *Journal of Information Systems Education*, vol. 28, no. 1, pp. 1–10, 2017.

[16] H. N. Mok, "Teaching tip: The flipped classroom," *Journal of information systems education*, vol. 25, no. 1, p. 7, 2014.

[17] T. Nagle, G. Birkbeck, N. Daly, S. Jones, J. O'Sullivan, and D. Sammon, "Methodological 'Learning-by-Doing' for Action Design Research," *Journal of Information Systems Education*, vol. 34, no. 3, pp. 293–306, 2023.

[18] C. Sibona, S. Pourreza, and S. Hill, "Origami: An active learning exercise for scrum project management," *Journal of Information Systems Education*, vol. 29, no. 2, pp. 105–116, 2018.

[19] D. M. Woods, "Active learning using debates in an IT strategy course," *Journal of Information Systems Education*, vol. 31, no. 1, pp. 40–50, 2020.

[20] M. Prince, "Does active learning work? A review of the research," *Journal of engineering education*, vol. 93, no. 3, pp. 223–231, 2004.

[21] A. MacKenzie, "Nudging lifelong learning and reflective thinking in engineering students utilizing LinkedIn learning," *International Journal of Advanced Corporate Learning*, vol. 16, no. 2, p. 57, 2023.

[22] P. Schloemer and K. Brenan, "From students to learners: Developing self-regulated learning," *Journal of Education for Business*, vol. 82, no. 2, pp. 81–87, 2006.

[23] L. Reginato, S. Durso, C. Nascimento, and E. Cornacchione, "Transfer of learning in accounting programs: The role of business games," *The International Journal of Management Education*, vol. 20, no. 1, p. 100592, 2022, doi: https://doi.org/10.1016/j.ijme.2021.100592,2022.

[24] N. Safitri, N. W. A. Pohan, D. I. Sensuse, D. Satria, and S. Al Hakim, "An Assesment of Knowledge Sharing System: SCeLE Universitas Indonesia," in *2019 3rd International Conference on Informatics and Computational Sciences (ICICoS)*, IEEE, 2019, pp. 1–6.

[25] A. P. Sasmito, D. Kustono, P. Purnomo, H. Elmunsyah, D. Nurhadi, and P. Sekarsari, "Development of Android-Based Teaching Material in Software Engineering Subjects for Informatics Engineering Students.," *Int. J. Eng. Pedagog.*, vol. 11, no. 2, pp. 25–40, 2021.

[26] H. Elmunsyah, G. R. Kusumo, U. Pujianto, and D. D. Prasetya, "Development of mobile based educational game as a learning media for basic programming in VHS," in *2018 5th International Conference on Electrical Engineering, Computer Science and Informatics (EECSI)*, IEEE, 2018, pp. 416–420.

[27] M. Binkley *et al.*, "Defining twenty-first century skills," *Assessment and teaching of 21st century skills*, pp. 17–66, 2012.

[28] W. N. Hidayat, T. A. Putri, N. T. Arsyillah, M. A. Bahris, H. Suswanto, and A. Hamdan, "Evaluation of user experience on learning management system for programming course through user experience questionnaire method," in *2023 Eighth International Conference on Informatics and Computing (ICIC)*, IEEE, 2023, pp. 1–6.

[29] R. Luckin and W. Holmes, "Intelligence unleashed: An argument for AI in education," 2016.

[30] N. Selwyn, *Should robots replace teachers?: AI and the future of education*. John Wiley & Sons, 2019.