Enhance the Understanding of Learning Sorting and Searching Algorithms through Card Ranking Methods (Game-Based Approach)

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ABSTRACT

Teaching sorting and searching algorithms in Data Structures and Algorithms courses is often challenging due to their abstract nature. Traditional lecture-based methods frequently fail to provide students with an intuitive understanding of these essential concepts, leading to poor engagement and comprehension. This research explores the use of a game-based learning approach, specifically the card ranking method, to address these challenges and enhance student learning. The study was conducted with the 2021/2022 batch of students enrolled in the Data Structures and Algorithms course. The card ranking method involved creating ten cards, each representing a number, and having ten students hold these cards. A sorting algorithm, such as insertion sort, was displayed on the screen, and the students physically enacted the algorithm by swapping positions based on the logic of the displayed algorithm. This interactive approach allowed students to visualize and actively participate in the sorting process, transforming an abstract concept into an engaging physical activity.

Findings revealed that this method significantly improved students' understanding of sorting and searching algorithms. Feedback collected from students indicated a high level of satisfaction, with many requesting the continuation of this method for teaching other algorithms. The activity fostered active participation, collaboration, and engagement, which are essential components of effective learning. This research underscores the potential of game-based learning approaches to address learning challenges in computer science education. By integrating interactive methods such as the card ranking method, educators can foster deeper comprehension and increase student interest in complex topics. Future work will explore the application of this method to additional algorithms and assess its scalability in larger classrooms.

Keywords: Data Structures and Algorithms, Game-Based Learning, Card Ranking Method, Sorting Algorithms, Searching Algorithms, Interactive Teaching.

INTRODUCTION

Teaching algorithms in computer science education is fundamental yet challenging due to their abstract nature. Sorting and searching algorithms, being the cornerstone of data manipulation and retrieval, are particularly difficult for students to comprehend when taught using traditional lecture-based methods. While theoretical concepts are essential, their lack of tangible or practical application often leaves students disengaged, struggling to visualize the mechanisms behind these algorithms. The complexity of algorithmic steps, combined with the absence of active learning strategies, creates a gap in understanding that hinders students from mastering these critical concepts.

Interactive teaching methods have gained recognition for their ability to address such challenges by fostering student engagement and promoting experiential learning. Game-based learning, a subset of interactive teaching, emphasizes active participation and real-world simulation, creating a dynamic learning environment that bridges the gap between theory and practice. In this context, the card ranking method was introduced as an innovative teaching approach to enhance students' comprehension of sorting and searching algorithms in the Data Structures and Algorithms course.

In the field of computer science education, sorting algorithms like bubble sort, insertion sort, and selection sort require a step-by-step understanding of comparisons, swaps, and iterations. Without a hands-on approach, these steps often appear convoluted, deterring students from fully grasping their underlying mechanisms. The card ranking method simplifies these processes by enabling students to physically enact algorithmic steps, thereby fostering a clearer understanding of their functionality.

Despite the importance of sorting and searching algorithms in computer science curricula, many students continue to face significant challenges in understanding their mechanisms. Feedback from students in the Data Structures and Algorithms course revealed that traditional teaching methods, including lectures and slide-based explanations, failed to cater to diverse learning styles. The abstract nature of algorithms often led to confusion, disengagement, and a lack of confidence in applying these concepts to real-world problems.

This learning gap not only impacts academic performance but also affects students' ability to solve algorithmic challenges in competitive programming and software development. Therefore, a more interactive and engaging teaching strategy was required to address these limitations and provide students with a deeper, more intuitive understanding of sorting and searching algorithms.

The primary objective of this study was to enhance students' comprehension of sorting and searching algorithms through an innovative, game-based learning approach. By employing the card ranking method, the research aimed to:

1. Simplify the understanding of sorting and searching algorithms by transforming abstract steps into a physical, visual, and interactive activity.
2. Increase student engagement and participation in the learning process by incorporating elements of collaboration and fun.
3. Address diverse learning styles by providing a hands-on experience that complements traditional teaching methods.
4. Evaluate the effectiveness of the card ranking method in improving students' knowledge and confidence in applying sorting and searching algorithms.
5. Encourage feedback-driven improvement of teaching methodologies for future batches of students in the Data Structures and Algorithms course.

By integrating these objectives, the study sought to redefine the teaching and learning experience, bridging the gap between theoretical understanding and practical application in computer science education.

LITERATURE REVIEW

There have been numerous efforts to integrate games into teaching computer science concepts, leveraging the engaging and interactive nature of games to simplify complex topics and improve student understanding. One such example is the work presented in [1], where a game-based approach is employed to teach graph theory topics, specifically focusing on Kruskal’s, Prim’s, and Dijkstra’s algorithms. The game, called "Ticket to Ride," involves students undertaking missions to connect one city to another. Through these missions, students inadvertently explore the practical implementation and application of the aforementioned algorithms, enabling them to grasp the concepts more effectively.

Another notable example is highlighted in [2], where the N-Puzzle game is used to teach state-space search and machine learning. This puzzle game offers a hands-on approach to understanding how algorithms navigate and solve state-space problems, making it an effective tool for demonstrating algorithmic principles in an engaging manner. Similarly, in the introductory artificial intelligence course at UC Berkeley, the Pac-Man game has been utilized to teach a range of AI concepts. Students learn about state-space search, adversarial search, Markov decision processes, reinforcement learning, and probabilistic tracking through practical scenarios within the game, which adds a layer of excitement and relevance to their learning experience.

[5] Presents a novel solution which combines a game-based learning approach with the use of engaging visualizations of algorithms in 2.5D. These visualizations add depth to the conceptual understanding of

algorithms, offering an immersive and interactive experience that bridges the gap between theory and practice. [6] Outlines the conceptual framework developed for animating algorithms, describes the implemented system, and provides several examples from the wide range of algorithms that have been animated.

Additionally, the Rook Jumping Maze has been used to teach uninformed search, stochastic local search, and machine learning, as described in [3]. This game provides students with the opportunity to experiment with search algorithms and optimization techniques in a controlled, yet entertaining environment. By navigating through the maze using these algorithms, students develop a deeper understanding of the strategies and challenges involved in solving complex computational problems.

These examples highlight the growing trend of incorporating game-based learning into computer science education. They demonstrate how games can transform abstract concepts into interactive, memorable experiences, making them valuable tools for teaching intricate topics effectively. In our work, we aimed to incorporate the card ranking method, which is a game-based approach where students can learn sorting and searching algorithms by playing the game physically rather than playing it on computers.

Game Description

The “Card Ranking Method” is an interactive approach to teaching algorithms, designed to make abstract concepts tangible and engaging. This method involves using a group of students, each holding a card with a unique number or label, to physically enact the steps of an algorithm. The process begins by assigning cards to students in random order and having them line up to represent an unsorted array.

The teacher then guides the students through the algorithm, step by step. For example, in an insertion sort, one student stands as the "sorted" section, while others take turns stepping forward to find their correct position. Similarly, in a bubble sort, students compare their cards with neighbors and swap positions if necessary, repeating until the line is sorted. Each action corresponds to a specific operation in the algorithm, such as a comparison or swap, making it easier for students to grasp the underlying logic.

This hands-on activity transforms theoretical learning into a collaborative and memorable experience. By actively participating, students better understand the mechanics of algorithms and retain the concepts more effectively. However, challenges like managing time for large groups or encouraging shy students to participate can arise. These can be addressed by breaking the activity into smaller subsets or assigning observer roles to less confident students. Overall, the Card Ranking Method provides an engaging way to bridge the gap between theory and practice in algorithmic learning.

Playing the Game

Using the Card Ranking Method as a game-like teaching tool involves a structured yet interactive approach that blends fun and learning. Here is how you can use the game effectively in the classroom:

- To begin, prepare a set of numbered cards
- Select the algorithm you want to demonstrate
- Gather a group of students in the batch 2021/2022
- Distribute one card to each student
- Arrange the students in a line, holding their cards in random order, to represent an unsorted array
- Before starting, provide a brief explanation of the algorithm, focusing on its basic operations, such as comparisons, swaps, or insertions.

Once the students are ready, guide them step by step through the algorithm's process. For example, in an insertion sort, the first student holds their position as the sorted section. The next student steps forward and compares their card with the sorted section, moving to the correct position based on the algorithm’s rules. The process continues until all students are positioned in ascending order, mimicking how the algorithm sorts elements. For a bubble sort, students compare their card with their immediate neighbor and swap positions if necessary, repeating this until the entire group is sorted.

Throughout the game, explain what each step represents in the context of the algorithm. Highlight key operations, such as the number of comparisons or swaps, and relate them to the theoretical complexity of the algorithm. To make the game more dynamic, introduce variations, such as timing the sorting process or having students' record observations about efficiency.

Once the sorting is complete, facilitate a discussion to reinforce the concepts. Ask students to reflect on their roles, share insights, and identify challenges they faced during the sorting process. This reflection helps connect the physical activity to the algorithm's logic and prepares them for further problem-solving exercises. By transforming abstract concepts into a hands-on game, this method not only enhances understanding but also makes learning algorithms an enjoyable and memorable experience.

Evaluation

An evaluation of the results of using a game-based approach to teach algorithmic concepts in the Data Structures and Algorithms course at our department was conducted last semester. A total of 41 undergraduate students enrolled in the course participated in the evaluation. The students were divided into eight groups, each named A, B, C, D, E, F, G, and H, respectively. Groups A through G consisted of five students each, while Group H had six students. To begin the activity, Group A was randomly selected to play the game.

The initial positions (unsorted array) of the students are shown in Figure (1), their final positions (sorted array) are depicted in Figure (2), and the displayed insertion algorithm is illustrated in Figure (3).

Figure 1: Initial Position of Students

Figure 2: Final Position of Students

Algorithm for Insertion Sort

```
Insertion_Sort (A)
        for j = 1 to A.length
                key = A[j]
                i = j - 1
                While i > 0 and A[i] > key
                        A[ i+ 1] = A[i]
                        i = i - 1
                A[i+1] = key
End
```

Figure 1: Insertion Sort Algorithm

The students were then asked to complete a questionnaire designed to evaluate the usability of the game, share their experiences, and provide their opinions on the learning impact of the card-ranking game in teaching algorithms. The questionnaire consisted of ten questions. Questions Q1-Q9 were based on a Likert scale (1: Strongly Disagree, 2: Disagree, 3: Neutral, 4: Agree, 5: Strongly Agree). Question 10 was an open-ended question, inviting students to discuss the strengths and weaknesses of the game, any challenges they encountered, and suggestions for potential improvements.

Table 1: Questionnaire Results

Q No.	Question	Answers (%)				
		1	2	3	4	5
1	The card ranking method helped me understand the sorting techniques better.	0	0	0	17.1	82.9
2	The game-like approach made learning about sorting techniques more enjoyable for me.	0	0	0	17.1	82.9
3	I feel more confident in my ability to apply sorting techniques after participating in the card ranking activity.	0	0	0	26.8	73.2
4	The card ranking method effectively engaged me in the learning process.	0	0	0	12.5	87.5
5	I would like to see more interactive activities like the card ranking method used in future lessons.	0	0	2.5	19.5	78
6	The instructions for the card ranking activity were clear and easy to follow.	0	0	0	19.5	80.5
7	I believe the card ranking method helped me retain information about sorting techniques better than traditional teaching methods.	0	0	0	24.4	75.6
8	The card ranking activity encouraged collaboration and discussion among classmates.	0	0	0	12.2	87.8
9	Overall, I found the card ranking method to be an effective way of learning about sorting techniques.	0	0	0	26.8	73.2

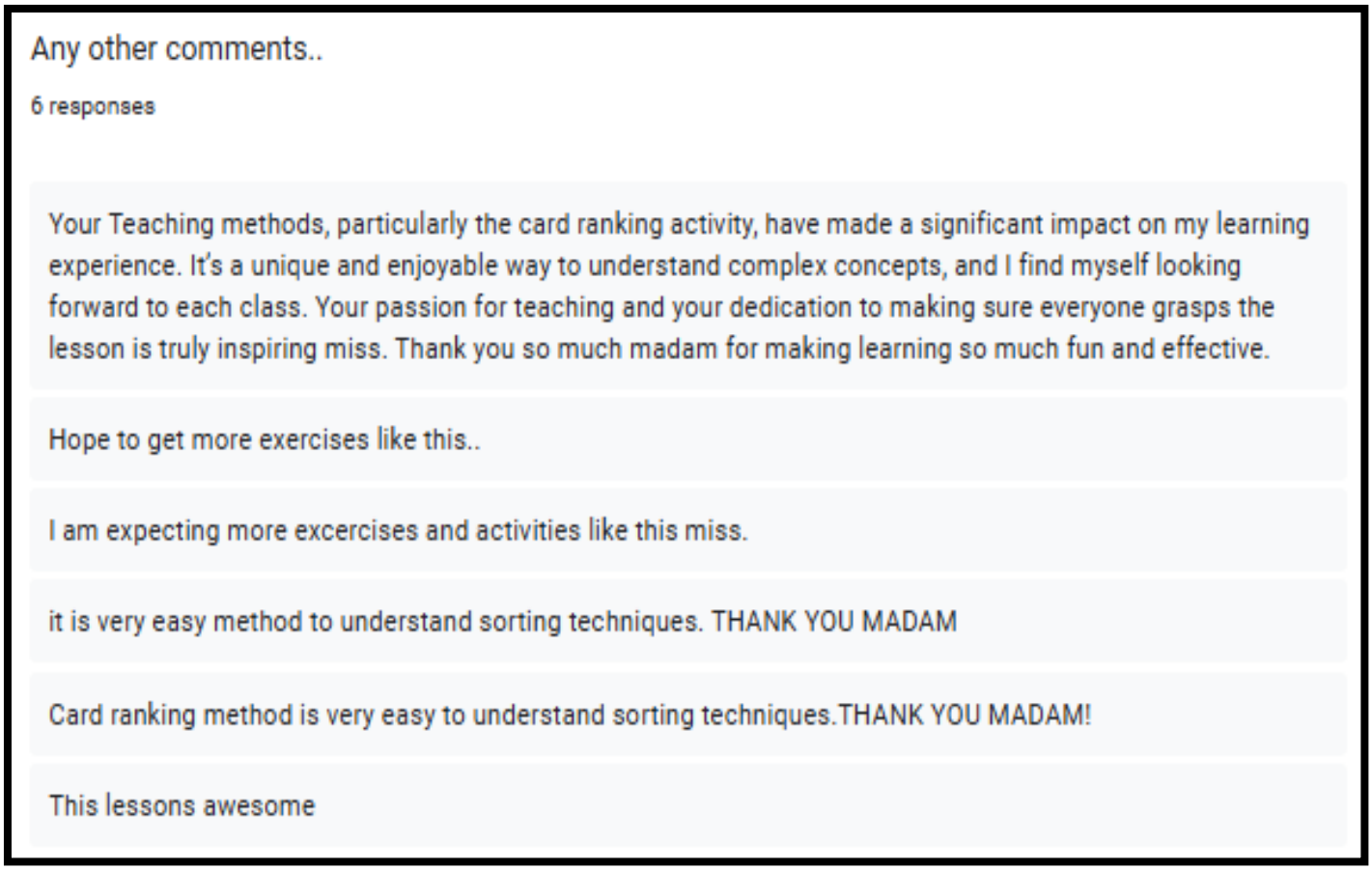

Figure 2: Feedback for Question No. 9

A large majority of students (82.9%) agreed or strongly agreed that the card-ranking method helped them understand sorting techniques better. Similarly, 82.9% of the students found the game-like approach enjoyable for learning sorting techniques. After participating in the activity, 73.2% of students felt more confident in their ability to apply sorting techniques. The method effectively engaged students, with 87.5% agreeing or strongly agreeing that it kept them involved in the learning process. A strong preference for more interactive activities was expressed, with 78% of students indicating they would like to see such methods used in future lessons. Students found the instructions clear and easy to follow, with 80.5% rating them positively. 75.6% of students believed that the card-ranking method helped them retain information about sorting techniques better than traditional teaching methods. The activity fostered collaboration and discussion among classmates, as evidenced by 87.8% of students agreeing or strongly agreeing. A significant majority (73.2%) rated the card-ranking method as an effective way of learning sorting techniques.

These results highlight the success of the card-ranking method in enhancing understanding, engagement, and confidence among students while promoting a collaborative and enjoyable learning environment. The feedback collected regarding the card-ranking game through the Google Form is attached in the appendix.

CONCLUSION AND FUTURE WORK

The card ranking method has proven to be an innovative and effective tool for teaching sorting and searching algorithms in the Data Structures and Algorithms course. By transitioning from traditional lectures to a game-based learning approach, students experienced increased engagement, interest, and improved academic performance. The physical enactment of algorithms allowed students to visualize and internalize the underlying mechanisms, addressing previous challenges in understanding these concepts. Feedback collected from the 41 participating students strongly indicated a preference for this interactive learning method, with many expressing enthusiasm for its continuation in future classes.

While the card ranking method demonstrated significant improvements in learning outcomes, it also highlighted the broader potential of incorporating active learning strategies into computer science education. This approach serves as a testament to how simple, yet creative interventions can transform the learning experience, making abstract concepts tangible and accessible.

For future work:

1. Extend the card ranking method to include more complex algorithms such as merge sort, quicksort, and graph traversal algorithms.

2. Conduct a comparative study to quantitatively measure the impact of game-based learning methods against traditional teaching approaches, focusing on long-term retention and problem-solving skills.

3. Develop a scalable framework that incorporates similar game-based methods for larger class sizes or online learning environments, potentially integrating digital tools to complement physical activities.

4. Explore the use of the card ranking method in other courses, such as Artificial Intelligence or Database Systems, to teach related concepts interactively.

By continually refining and expanding the application of the card ranking method, teachers can build on its success to cultivate a deeper and more meaningful understanding of algorithms, thereby equipping students with the skills necessary for their academic and professional endeavors.

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APPENDIX

Student Feedback for the Card Ranking Game

Feedback: Enhance the Understanding of Algorithms through Game-based Approach (Card Ranking Method)

41 responses

Publish analytics

The card ranking method helped me understand the sorting techniques better.

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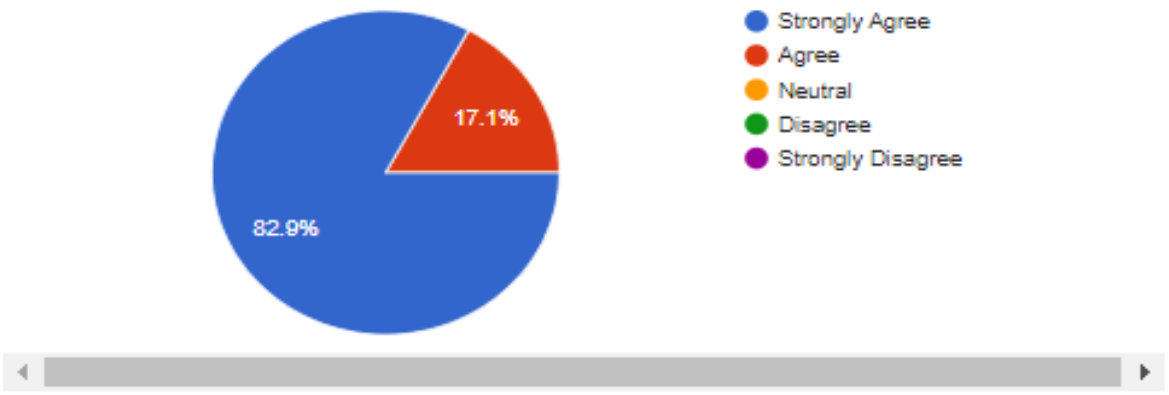
41 responses



The game-like approach made learning about sorting techniques more enjoyable for me.

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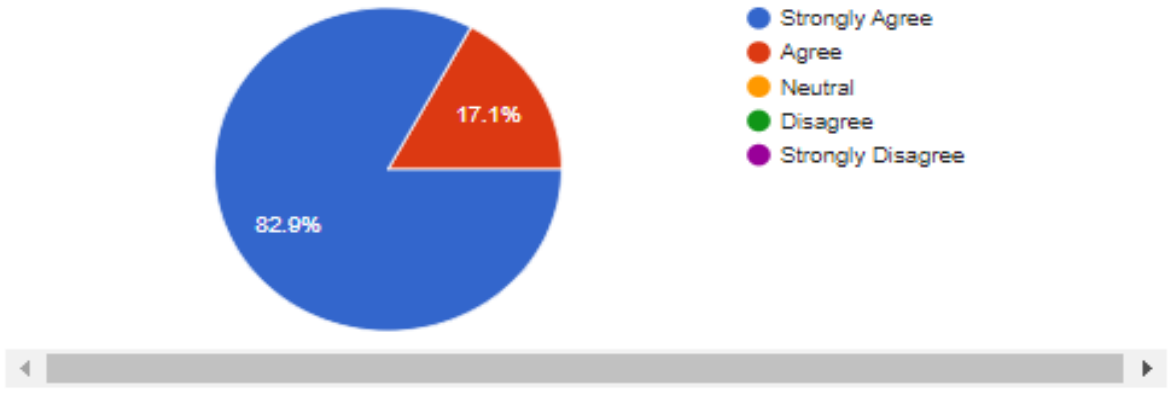
41 responses



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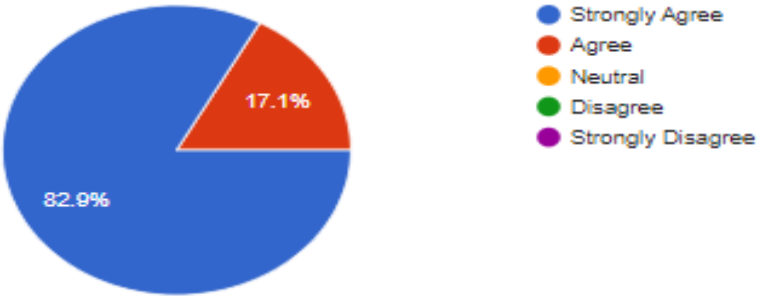

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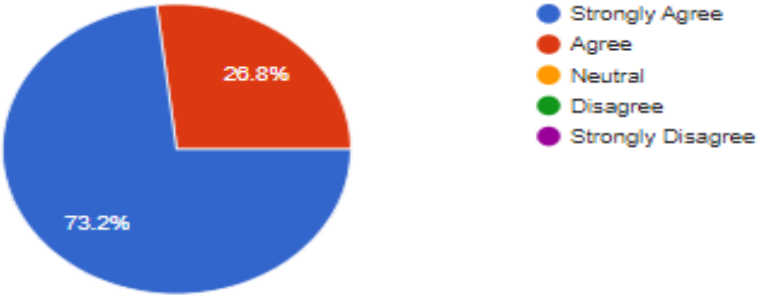
I feel more confident in my ability to apply sorting techniques after participating in the card ranking activity.

41 responses



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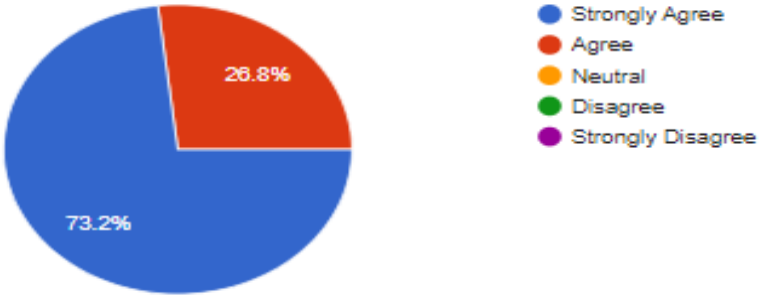

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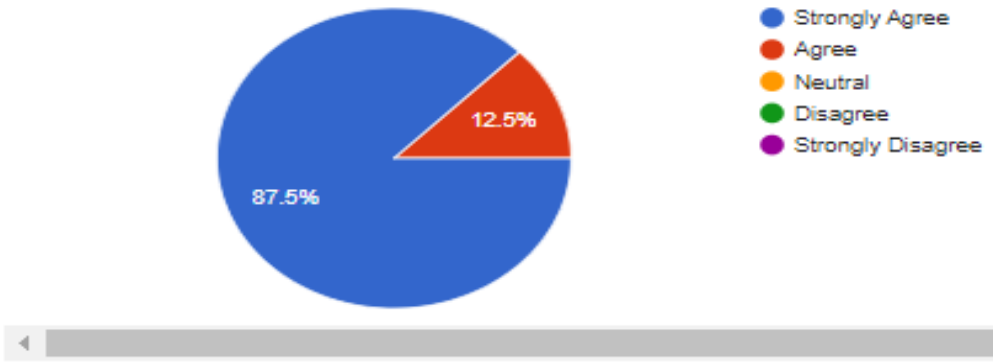
The card ranking method effectively engaged me in the learning process.

40 responses



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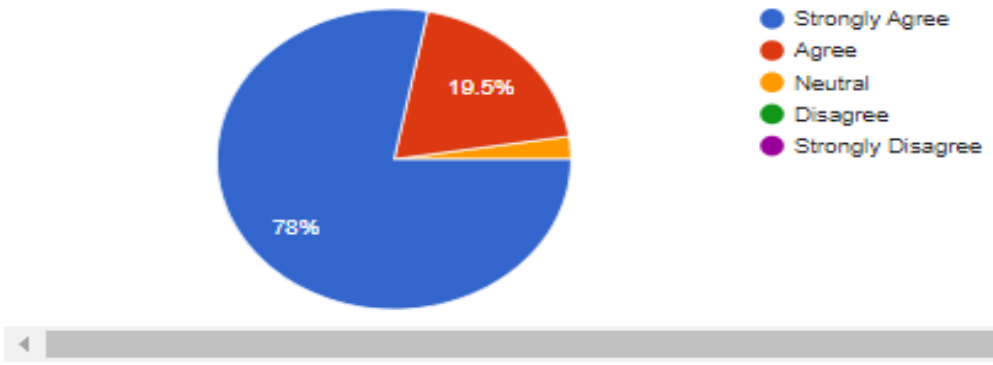
I would like to see more interactive activities like the card ranking method used in future lessons.

41 responses



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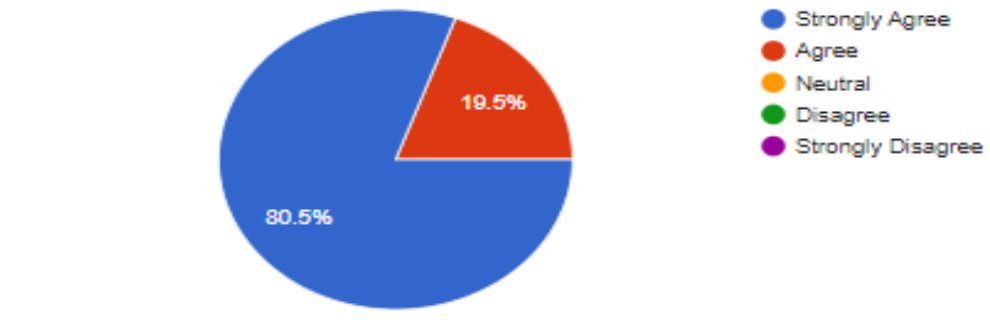
The instructions for the card ranking activity were clear and easy to follow.

41 responses



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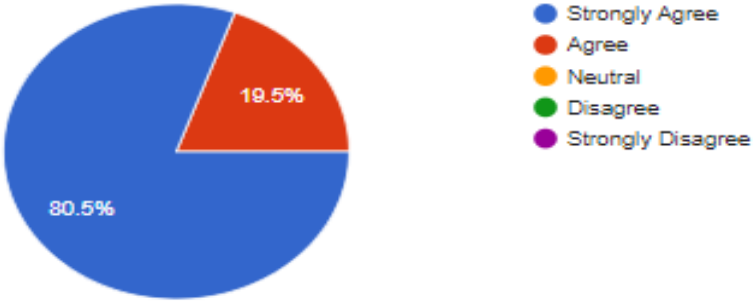

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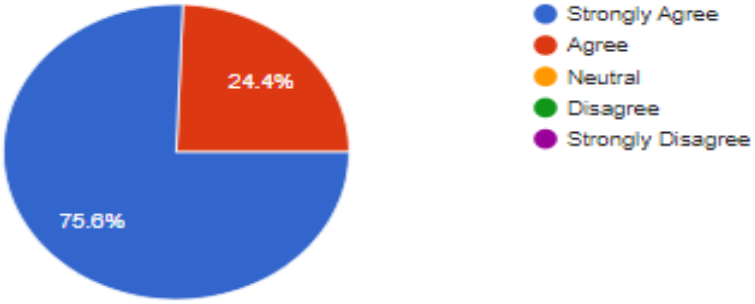
I believe the card ranking method helped me retain information about sorting techniques better than traditional teaching methods.

41 responses



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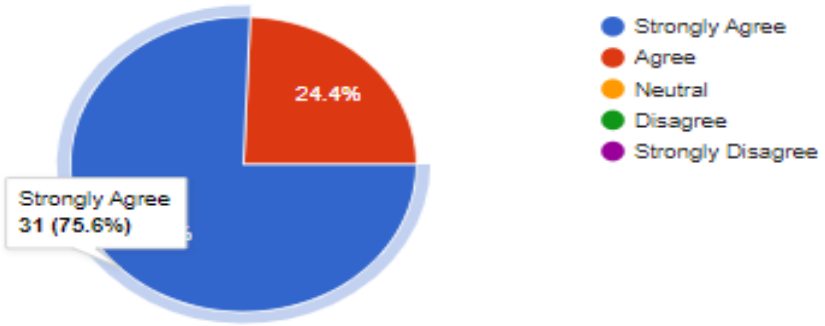

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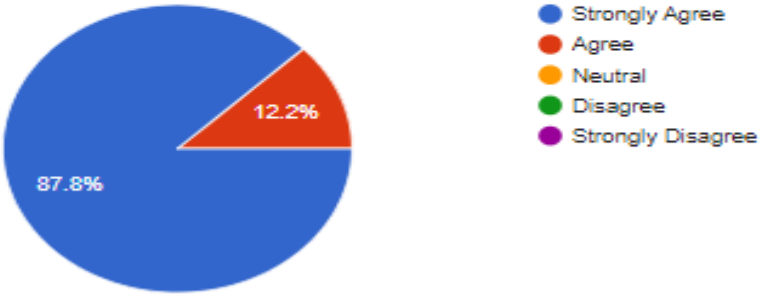
The card ranking activity encouraged collaboration and discussion among classmates.

41 responses



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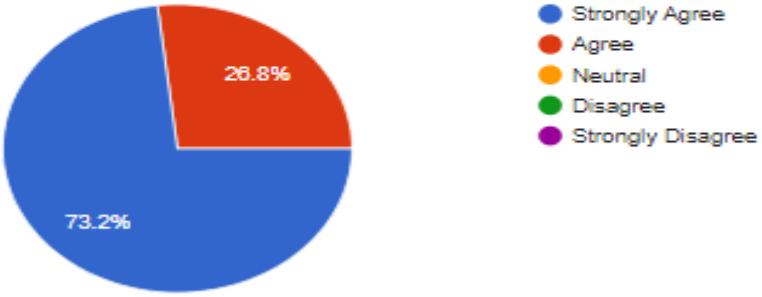
Overall, I found the card ranking method to be an effective way of learning about sorting techniques.

41 responses



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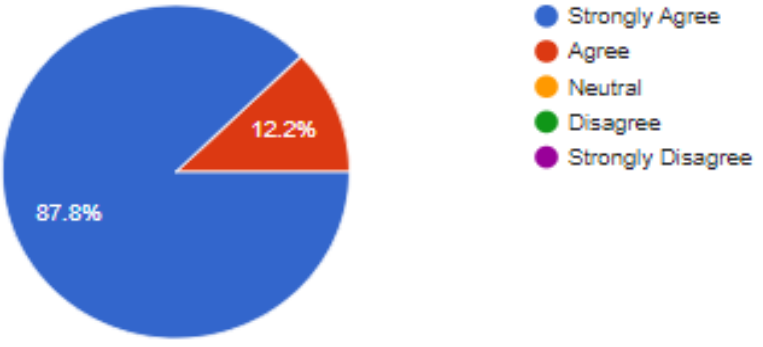

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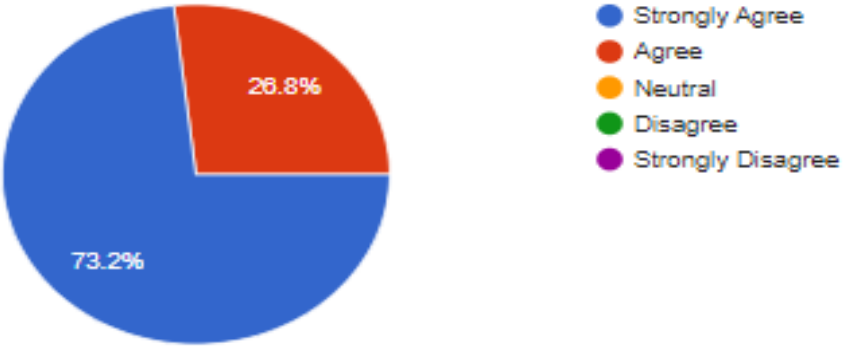

Any other comments..

6 responses

Hope to get more exercises like this..

I am expecting more excercises and activities like this miss.

This lessons awesome

Card ranking method is very easy to understand sorting techniques.THANK YOU MADAM!

it is very easy method to understand sorting techniques. THANK YOU MADAM

Your Teaching methods, particularly the card ranking activity, have made a significant impact on my learning experience. It's a unique and enjoyable way to understand complex concepts, and I find myself looking forward to each class. Your passion for teaching and your dedication to making sure everyone grasps the lesson is truly inspiring miss. Thank you so much madam for making learning so much fun and effective.