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Beyond the Hive Mind: Leveraging the Artificial Bee Colony Model for Collaborative Learning in English Language Teaching

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Abstract

Innovative teaching strategies that support a variety of learning styles and promote productive collaboration are desperately needed, as the number of ESL students enrolled in university courses rises. This study conceptualizes the integration of the Artificial Bee Colony (ABC) model with constructivist principles to enhance collaborative learning in English Language Teaching (ELT). The expected outcomes from the proposed Design and Development Research (DDR) study include improved group formation, enhanced student engagement and participation, more effective task allocation, and better academic performance.

1. Introduction

Universities are seeing an increase in the number of English Language Learners (ELLs), which calls for creative solutions to provide productive learning environments. Collaborative learning techniques have become a potent instrument that encourages knowledge sharing and peer engagement (Mora et al., 2020). This paper explores the potential of applying Swarm Intelligence (SI), a subfield of Artificial Intelligence (AI) inspired by the collective behaviour of natural systems, to enhance collaborative learning practices at the university-level.

This section introduces the concepts of Swarm Intelligence (SI) and the Artificial Bee Colony (ABC) model and describes how SI and ABC fit into the world of English Language Teaching (ELT) for learners at different levels.

1.1 Swarm Intelligence (SI)

Swarm Intelligence (SI), a fascinating framework within the Artificial Intelligence (AI) field, draws inspiration from the group behaviors of social insects such as bees and ants and other animals such as birds and fish. It entails the investigation of how numerous simple agents in decentralized, self-organizing systems collaborate to resolve complex problems in robust ways.

Ahmed and Glasgow (2012) shared that SI benefits from the cooperation of numerous simple agents, contrary to classic AI techniques that depend on a single controller. Every agent in the swarm communicates with its surroundings and other agents while adhering to a set of fundamental guidelines. As a result of these interactions, the swarm as a whole develops sophisticated behaviour that frequently surpasses the capacities of any one member (Tang et al., 2021). The key characteristics of SI are as presented in Figure 1.

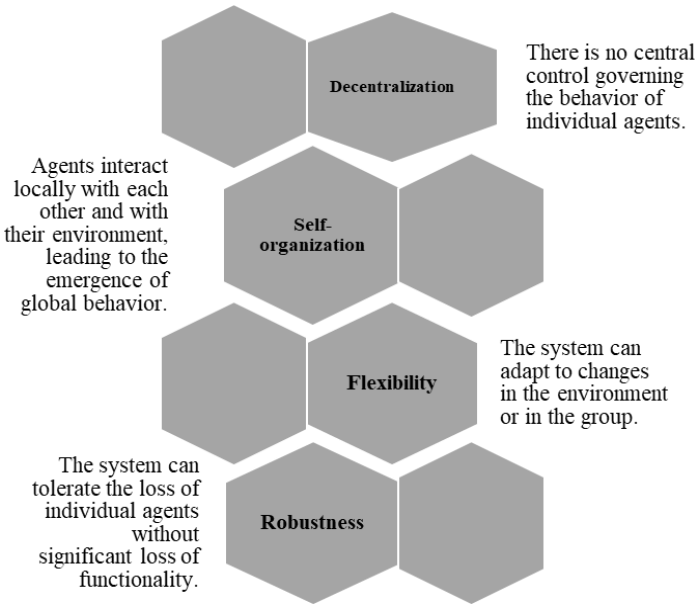

Fig 1. *Key Characteristics of Swarm Intelligence (SI)*

SI algorithms have been developed to mimic the natural behaviours of bee swarms, ant colonies, bird flocks and fish schools to be applied to various optimization and problem-solving tasks in the fields of AI and finance (Rosenberg et al., 2017). It is particularly useful in understanding and applying tactics to adapt to changes in the systems environment without needing significant modifications. As emphasised by Ahmed and Glasgow (2012), it also provides a framework derived from the nature which allows multiple workers or agents to work together parallelly and simultaneously to solve different parts of a problem, guaranteeing speed and efficiency.

Recently, various SI algorithms such as the Artificial Bee Colony (ABC), Particle Swarm Optimization (PSO) model and Ant Colony Optimization (ACO) models are being explored for the use of other global sectors such as education, logistics and healthcare. SI systems are very effective in practice, but they are also simple to build because of the rules that regulate the behaviour of the agents in the system.

1.2 Artificial Bee Colony (ABC) Model

The ABC model is an SI algorithm inspired by the foraging behavior of honey bees. Imagine a swarm of bees diligently searching for nectar, a valuable resource for the hive. The ABC model, proposed by Karaboga and Basturk (2007) mimics this process to find optimal solutions for complex problems by deploying three types of virtual bees: Employed Bees, Onlooker Bees, and Scout Bees.

The employed bees are linked to particular food sources (possible fixes) that they previously found. They take advantage of these resources, looking around for richer nectar (better solutions). Next, motivated by the "waggle dance" performed by actual bees, Employed Bees inform Onlooker Bees in the hive about the quality of their food sources. The energy of the dance conveys the depth of the source, and Onlooker Bees make their selection of a source based on this information. A food source is abandoned when its supply runs out or when a solution is no longer the best option. Then, Scout Bees explore their surroundings for wholly undiscovered food sources (or novel solutions). Figure 2 presents a typical pathway for the ABC model as illustrated by Balasubramani and Marcus (2013).

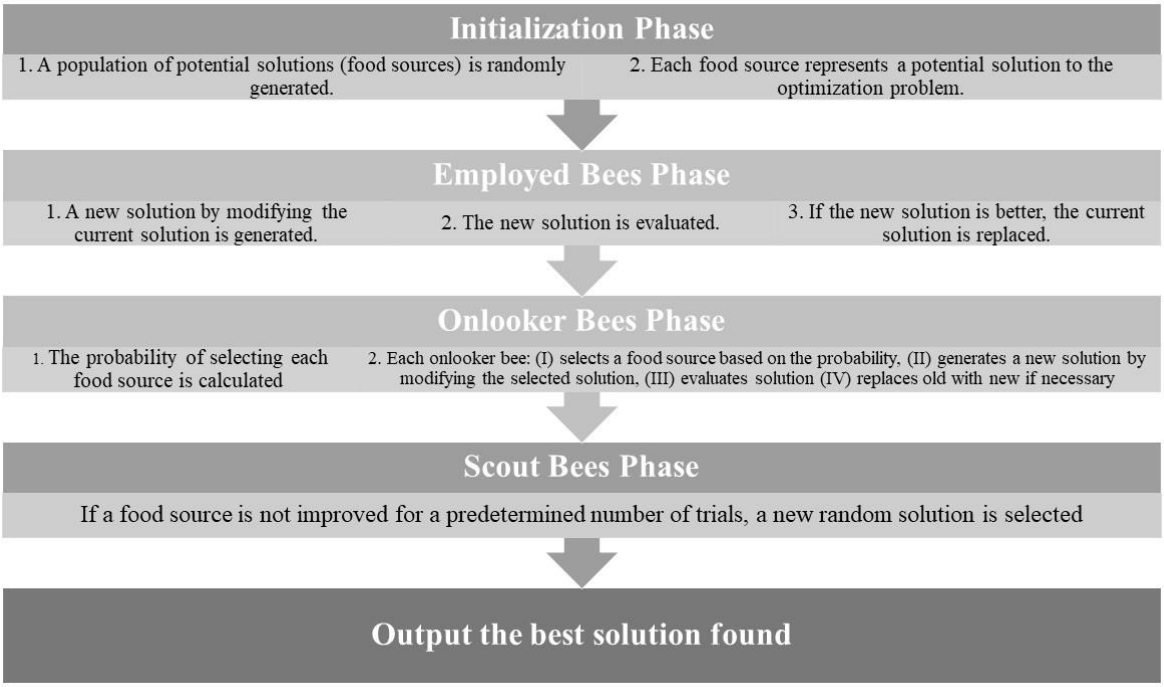

Fig. 2 *The Artificial Bee Colony Algorithm*

Due to its adaptability and effectiveness, the ABC algorithm is a potent tool for resolving a variety of real-world optimization issues in a variety of industries. Honey bees' natural foraging behavior is modelled by ABC, which offers reliable, flexible, and effective solutions to challenging problems.

This includes the education sector where classroom teaching and learning is concerned. Using the core concept of ABC, it can be applied innovatively to promote collaborative learning, optimize teaching strategies, and enhance student engagement for many subjects. Particularly, this study believes that the ABC model has the ability to optimise group formation and learning task allocation in collaborative learning in ELT, resulting in more effective and efficient learning experiences for students.

1.3 The Need for this Study

It is paramount to start looking at ELT and ESL learning from the AI perspective. This pressing need is fueled by the growing demand for effective collaboration in classroom and beyond (Singh & Bhuyan, 2024). The number of ESL students in university classrooms is rising and their varied learning styles may no longer be accommodated by traditional instructional methods; in fact, the collaborative learning approach needs to be adapted to support e-learning and blended learning. Successful ELT requires peer engagement, information exchange, and a sense of community, all of which are fostered via collaborative learning (Chen et al., 2020).

The main problem that can be theorized for collaborative learning in a blended learning environment is that, the processes used now to develop collaborative groups may be random or subjective, failing to take into account each student's unique strengths and weaknesses. For instance, teachers are more inclined to form groups based on personal observations or student preferences (Revelo-Sánchez et al., 2021). Although this can be beneficial in building friendships, it may disregard different learning methods and ability levels. For example, pairing a shy student with another shy student could prevent them from participating fully (Nyborg et al., 2023). In addition, allocating tasks may also not be the best way to maximise effective collaborative learning outcomes. If a student finds a task difficult or feels that they are not being sufficiently challenged, this might cause frustration (Nhan & Nhan, 2019).

This is where the ABC may come in; In a novel approach, this study proposes that the ABC model may help teachers create more balanced groups and assignments that are tailored to each student's preferred learning style by taking into account individual strengths and weaknesses. This can make for a more fruitful and engaging collaborative learning environment for a language subject. While collaborative learning or computer assisted collaborative learning (CACL) are well-established approaches, the idea of using the ABC model in ELT is very new. Hence, this study has the potential to revolutionize collaborative learning strategies for ELLs using frameworks from AI and offer insightful new information.

2. Research Methodology

This section entails the proposed research methodology to develop a framework utilizing the Artificial Bee Colony (ABC) model to enhance collaborative learning in ELT. The Design and Development Research (DDR) methodology developed by Richey and Klein (2014) is chosen to guide the framework development process following the Type II inquiry for model research. DDR is an iterative cycle of design, development, evaluation, and refinement that is used to create and test educational tools, processes, or interventions. It is a methodical yet flexible approach to research according to Jaya et al. (2021). The methodology is to be carried out in a 3-phase framework of DDR as shown in Figure 3.

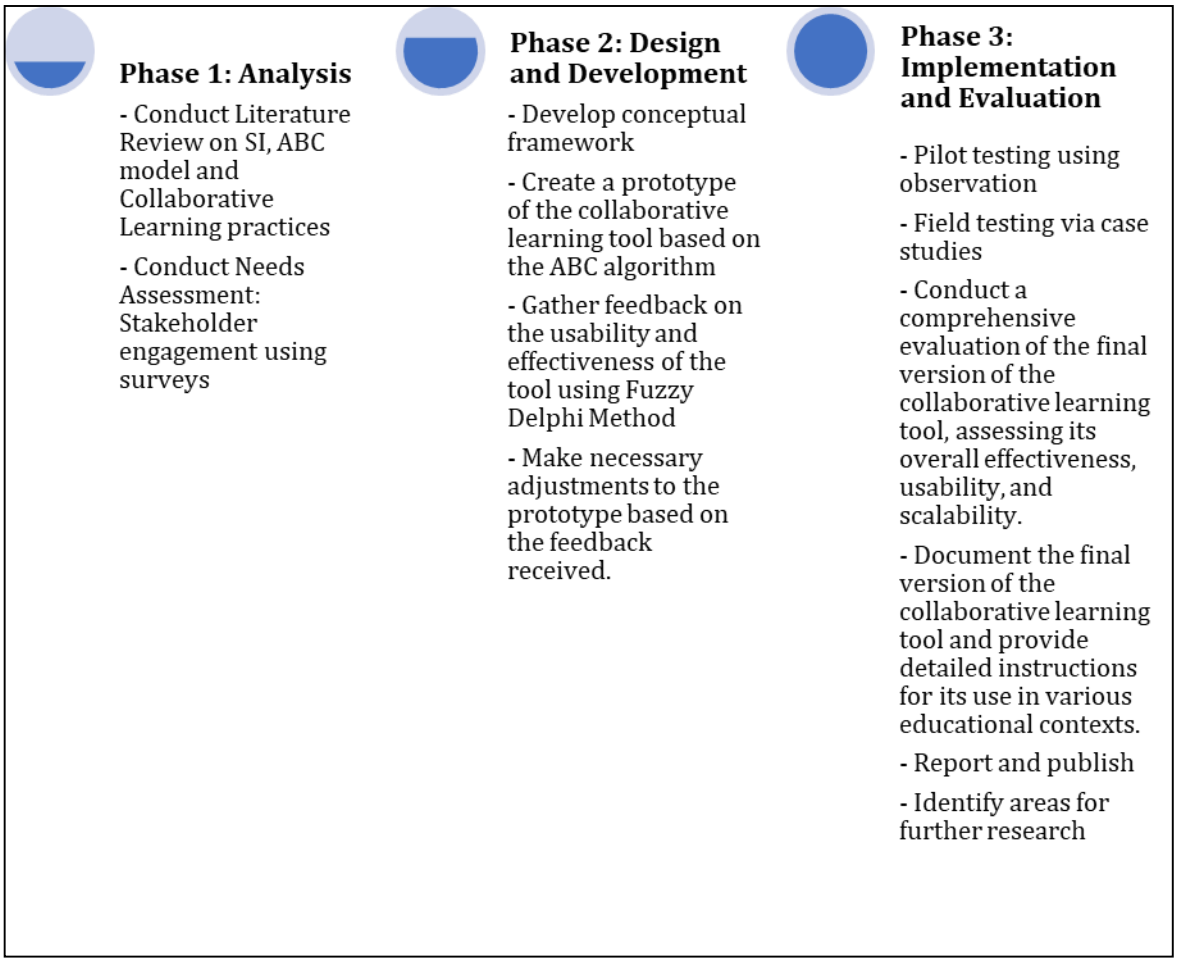

Fig. 3 The *3-Phase Framework of DDR for the Current Study*

By adhering to the structured DDR approach, the study aims to develop an enhanced collaborative learning framework for ELT through the innovative application of the ABC model, ultimately to promote AI-driven educational practices.

2.1 Research Objectives and Questions

For the DDR methodology, research objectives and questions are best categorized following the three phases for clarity. Table 1 presents the research objectives and questions for this study.

Table 1 *Research Objectives and Research Questions*

Phase/ Research Objectives and Questions	Phase 1: Analysis	Phase 2: Design and Development	Phase 3: Implementation and Evaluation
Research Objectives	1. To identify current challenges in collaborative learning practices within ELT. 2. To understand the potential benefits of integrating the ABC model in ELT. 3. To explore stakeholders' perspectives on the role of AI-driven approaches for collaborative learning.	4. To evaluate prototype based on formative feedback from small-scale pilot tests.	5. To evaluate the impact of the ABC-driven collaborative learning tool on student engagement, collaboration, and learning outcomes.
Research Questions	1. What are the current challenges in collaborative learning practices within ELT? 2. What are the potential benefits of integrating the ABC model in ELT? 3. What are the stakeholders' perspectives on the role of AI-driven approaches for collaborative learning?	4. How does the prototype collaborative learning tool perform in initial evaluations with small groups of ESL students and teachers?	5. How does the ABC-driven collaborative learning tool impact learning outcomes in a real-world classroom setting?

These research questions and objectives ensure a comprehensive DDR-based investigation into the use of the ABC model to enhance collaborative learning in ELT.

3. Expected Outcomes

The research will be conducted over an 18-month period, divided into three distinct phases of Analysis, Design and development and Implementation and evaluation. The expected outcomes from this study can be divided into two categories.

Firstly, the collaborative learning tool is expected to enhance collaborative learning practices using more effective task allocation that matches student abilities and preferences. This may ultimately lead to increased engagement and participation. The independent variable for this measurement would be 'the use of the ABC model' while the dependent variables will be 'student engagement' and 'peer interactions'. This can be measured by tracking the number of contributions per student during group tasks, using observation and participation logs. In addition, task completion rates and quality of work before and after the implementation of the ABC model can also be compared and measured.

Secondly, the scalability and sustainability of the framework can also be studied to inform of the effectiveness of adapting AI-based concepts into ELT practices. This may generate recommendations for future research and potential integration with other AI-driven educational technologies. The framework can be scored with usability scores from surveys using standardized tools like the System Usability Scale (SUS). Furthermore, implementation success rates across different classrooms and institutions may be tracked through implementation reports and case studies by involving a sizeable research team.

4. Conclusion

In conclusion, through a structured Design and Development Research (DDR) methodology encompassing analysis, design and development, and implementation and evaluation phases, the research will address current challenges in collaborative learning. In the field of ELT, this work has the potential to spark discussions among educators and scholars. It is hoped to promote cooperation between AI and education experts to create cutting-edge teaching strategies and increase awareness of the potential of swarm intelligence for the education sector.

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Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

The authors confirm shared responsibility for this paper. Venosha Ravana was responsible for the study conception and design, while Dr. Thilip Kumar Moorthy was responsible for the manuscript preparation. Sarala Thulasi Palpanadan was responsible for proofreading and editing.

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