Two POGIL Activities on Search Concepts and Strategies

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Course CS0, CS1, Data Structures

Programming Language None, Pseudocode

Resource Type Lab

CS Concepts Searching Algorithms, Trees

Knowledge Unit N/A

SYNOPSIS

These two team-based classroom activities are designed to help students understand key concepts used in artificial intelligence (AI) to search for possible solutions to problems. These activities are designed for use in Process Oriented Guided Inquiry Learning (POGIL), where student teams work during class time with active facilitation by an instructor or TA.

After completing these activities, students should be able to:

- Define and give examples of key terms, including: action, state, initial state, goal state, goal test, transition function, path, path cost function, state space
- Define and identify goal state problems and goal path problems.
- Describe the general structure of search problems, and specific strategies, including: breadth-first, depth-first, depth-limited, random-first, bi-directional, best-first
- Describe uninformed and informed search.
- Describe the value of path cost and heuristic functions.

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KEYWORDS

artificial intelligence, process oriented guided inquiry learning, POGIL, search, trees

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1 ENGAGEMENT HIGHLIGHTS

These activities are designed for *Process-Oriented Guided Inquiry Learning (POGIL)* [1,2]. In POGIL, students work during class time in structured teams with assigned roles (e.g., reporter, presenter). The instructor is an active facilitator, not a lecturer or passive observer. A POGIL activity is specifically designed using *learning cycles* that guide students to *explore* information that is provided, *invent* their own understanding of key concepts, and then *apply* those concepts. Thus, in POGIL students interact to construct their own understanding, as described in the *ICAP framework* [3]. A POGIL activity also helps students to practice *process skills* such as teamwork, communication, critical thinking, and problem solving. Typically, a POGIL activity is students' first exposure to new content, which is then reinforced and expanded through readings, recorded lectures, homework, and/or projects.

Thus, these activities incorporate several evidence-based practices. They *use well-structured collaborative learning* (POGIL). They *encourage student interaction* since students work in teams to understand concepts and practice communication, teamwork, and other process skills, and *provide opportunities for interaction with faculty* since the instructor observes and interacts with the teams and individual students throughout the activity. They also *address misconceptions*, by showing students that CS is often collaborative, that the final answer matters less than the process used to reach it, and that problems often have multiple solutions.

2 ACTIVITY OVERVIEW

The first activity is *Search 1: Concepts*, and Table 1 lists the sections. Sections A, B, and C introduce three search problems (*8 Puzzles*, *Normal Magic Squares*, and *8 Queens*) with different characteristics to engage students and provide a foundation for later concepts. Sections D, E, and F use these search problems to help students understand and apply concepts such as states (initial and goal), actions (applicable and inapplicable), paths, cost functions, and search spaces. Sections G and H could be skipped depending on instructor preference and student background. Section G reviews factorials (n! = 1*2*…*n) as a way to calculate the size of a state space. Section H introduces the *Traveling Salesperson Problem* as a more realistic example.

The second activity is *Search 2: Strategies*, and Table 2 lists the sections. Sections A and B explore how search can be represented as a tree that can be explored in a variety of ways (e.g., breadth-first, depth-first). Sections C, D, and E explore variations, including different cost functions, bidirectional search, and heuristics. Section F explores pseudocode for a search algorithm, and could be expanded with start code (for less experienced students), or skipped (e.g., for CS0, or for advanced students).

Table 1: Sections in *Search 1: Concepts*

Time	Section Name
8 min	A. 8 Puzzles
8 min	B. Normal Magic Squares
6 min	C. 8 Queens Puzzle
10 min	D. States & Actions
10 min	E. Paths & State Space
10 min	F. Searching State Space
8 min	G. Analysis using Factorial (optional)
10 min	H. Traveling Salesperson Problem (optional)

Table 2: Sections in *Search 2: Strategies*

Time	Section Name
12 min	A. Search Structure
10 min	B. Search Strategies
10 min	C. Search Variations
14 min	D. Search Direction
20 min	E. Informed Search
7 min	F. Pseudocode (optional)

3 RECOMMENDATIONS

These activities were originally developed and used in a CS elective (*Artificial Intelligence*) as part of a unit on problem solving and search, and parallel examples and contents in a popular textbook [4, chapter 3]. These activities were also used in an introductory CS course (*Computing and Cognition*) designed for students in psychology, neuroscience, and related disciplines, to supplement a chapter on decision structures [5, chapter 7].

The activities focus on terminology and high-level concepts, and seek to minimize prerequisite knowledge. The activities are split into sections with time estimates for each section and question (see Tables 1 and 2); this helps an instructor decide which sections to use. Note that timing will vary based on the instructor's experience with POGIL and on students' experience with basic mathematics, computing, and POGIL; as instructors and students gain experience with POGIL, activities usually take less time.

The instructor's version of each activity (available on request from the author) includes sample answers to each question, notes on questions or sections that could be skipped, and notes on when to ask teams to check in with the instructor or share some of their responses with other teams.

While teams work on the activity, the instructor should continually circulate to observe and listen, offer suggestions, help teams to work more effectively, and lead occasional short discussions of key questions or problems that teams encounter. The instructor should try not to give or confirm answers, but encourage teams to discuss and reach consensus. It is usually unnecessary to grade each activity, since all teams should reach similar (correct) answers. Some instructors give a few points for completion or participation to encourage students to give the activity their full attention, or give a quiz on key ideas (e.g., during the next class). Instructors might also use rubrics designed to evaluate student process skills [6].

Depending on the course, student background, etc., an instructor can decide which activities and sections to use, and create subsequent assignments. For example, in an AI elective students could design, code, and test code to solve a search problem, and perhaps analyze the impact of different strategies. In CS1 or CS2 students learning about arrays could write programs to generate and test randomly generated solutions to the problems in *Search 1*. In CS2 or Data Structures students learning about trees might complete starter code to solve one or more problem. In non-majors' course (CS0) students might be asked to analyze and describe a different search problem (or a real world problem) using the terminology and concepts developed in *Search 1*. After *Search 2*, CS0 students could also trace or draw trees for other problems.

4 RELATED ONLINE RESOURCES

For more info on POGIL in CS courses, see the CS-POGIL website and community (http://cspogil.org). For general info on POGIL, see The POGIL Project (https://pogil.org). Consider attending a 1/2-day, 1-day, or multi-day POGIL workshop to learn more about POGIL principles, how to effectively facilitate a POGIL classroom, and how to develop effective POGIL activities.

5 MATERIALS

The zipped file contains the student versions: *Search 1: Concepts (Student).pdf* and *Search 2: Strategies (Student).pdf*. These could be printed and distributed (one copy per student or per team) or posted as PDFs or Google Docs. Please contact the author for the teacher versions with solutions and additional information.

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7 REFERENCES

[1] Moog, R. S., and Spencer, J. N. 2008. *Process-Oriented Guided Inquiry Learning*. ACS Symposium Series vol 994, American Chemical Society.

[2] Simonson, S. R. (ed) 2019. *POGIL: An Introduction to Process Oriented Guided Inquiry Learning for Those Who Wish to Empower Learners*. Stylus Publishing.

[3] Chi, M. T. H., and Wylie, R. 2014. The ICAP framework: Linking cognitive engagement to active learning outcomes. *Educational Psychologist*, 49, 4, 219-243. DOI=https://doi.org/10.1080/00461520.2014.965823

[4] Russell, S. and Norvig, P. 2010. *Artificial Intelligence: A Modern Approach* (3rd ed). Pearson.

[5] Zelle, J. 2016. *Python Programming: An Introduction to Computer Science* (3rd ed). Franklin, Beedle, & Assoc.

[6] Reynders, G., Lantz, J., Ruder, S. M., Stanford, C. L., Cole, R. S. 2020. Rubrics to assess critical thinking and information processing in undergraduate STEM courses. *International Journal of STEM Education*, 7, 9