TLEF Project – Final Report

Report Completion Date: (2021/04/30)

1. PROJECT OVERVIEW

1.1. General Information

Project Title:	Experiential Learning in Game Theory		
Principal Investigator:	Jonathan Graves & Rik Blok		
Report Submitted By:	Jonathan Graves		
Project Initiation Date:	1-April-2018	**Project Completion Date:**	1-April-2021
Project Type:	☐ Large Transformation ☒ Small Innovation ☐ Flexible Learning ☐ Other: [please specify]		

1.2. Project Focus Areas – *Please select all the areas that describe your project.*

☒ Resource development (e.g. learning materials, media)

☐ Infrastructure development (e.g. management tools, repositories, learning spaces)

☒ Pedagogies for student learning and/or engagement (e.g. active learning)

☐ Innovative assessments (e.g. two-stage exams, student peer-assessment)

☐ Teaching roles and training (e.g. teaching practice development, TA roles)

☐ Curriculum (e.g. program development/implementation, learning communities)

☐ Student experience outside the classroom (e.g. wellbeing, social inclusion)

☒ Experiential and work-integrated learning (e.g. co-op, community service learning)

☐ Indigenous-focused curricula and ways of knowing

☐ Diversity and inclusion in teaching and learning contexts

☐ Open educational resources

☐ Other: [please specify]

1.3. Final Project Summary

In this small TLEF project, we developed a web-based educational application (Project AXLRD) which allows students to engage in experiential learning in game theory, using a setting based on the seminal experiment of Axelrod[1]. This application uses a "snap-together" user interface which allows students with no programming experience to develop complex interactive strategies, then play them against other students in a re-creation of Axelrod's repeated games tournament. This tool encourages experimentation and engagement in the Kolb cycle[2] of experiential learning, creating a more concrete and authentic understanding of a complex theoretical area of applied game theory. We also developed a series of teaching and learning aides to support instructors using the Project AXLRD tool, including (i) lesson plans, (ii) lecture slides, and (iii) assessments.

1.4. Team Members – *Please fill in the following table and include **students**, undergraduate and/or graduate, who participated in your project.*

Name	Title/Affiliation	Responsibilities/Roles
Jonathan Graves	Assistant Professor of Teaching (UBC-V – Vancouver School of Economics)	Principal investigator
Rik Block	Sessional Lecturer (UBC-V Computer Science)	Principal Investigator
Saffrin Granby	Undergraduate Student (UBC-V)	Programmer
Abid Salahi	Undergraduate Student (UBC-V)	Programmer
Napat Karnsakultorn	Undergraduate Student (UBC-V)	Research Assistant

1.5. Courses Reached – *Please fill in the following table with **past**, **current**, and **future** courses and sections (e.g. HIST 101, 002, 2017/2018, Sep) that have been/will be reached by your project, including courses not included in your original proposal (you may adapt this section to the context of your project as necessary).*

Course	Section	Academic Year	Term (Summer/Fall/Winter)
ECON 221	TBA	2022-Future	Summer
ECON 421	TBA	2022-Future	Spring or Fall
CPSC 100	921	2021	Summer
ECON 221	004	2020/2021	Spring
ECON 421	002	2020/2021	Spring
ECON 221	003	2020/2021	Fall
CPSC 100	201	2020/2021	Spring
CPSC 100	921	2020	Summer
ECON 221	003	2019/2020	Fall
ECON 221	001	2019/2020	Spring

[1] Axelrod, Robert. 1980. "More Effective Choice in the Prisoner's Dilemma." Journal of Conflict Resolution 24 (3): 379–403. https://doi.org/10.1177/002200278002400301.

[2] Kolb, David A., Richard E. Boyatzis, and Charalampos Mainemelis. "Experiential learning theory: Previous research and new directions." Perspectives on thinking, learning, and cognitive styles 1.8 (2001): 227-247.

2. OUTPUTS AND/OR PRODUCTS

2.1. *Please **list** project outputs and/or products (e.g. resources, infrastructure, new courses/programs). Indicate the current location of such products and provide a URL if applicable.*

Product(s)/Achievement(s):	Location:
Project AXLRD interactive website	https://jonathanlgraves.arts.ubc.ca/project-axlrd-experiential-learning-in-game-theory/
Project AXLRD instructions and slides (lecture)	See above
Assessment and lesson plans	See above

2.2. Item(s) Not Met – *Please list intended project outputs and/or products that were not attained and the reason(s) for this.*

Item(s) Not Met:	Reason:
NA	NA

3. PROJECT IMPACT

3.1. Project Impact Areas – *Please select all the areas where your project made an impact.*

☒ Student learning and knowledge

☒ Student engagement and attitudes

☐ Instructional team-teaching practice and satisfaction

☐ Student wellbeing, social inclusion

☐ Awareness and capacity around strategic areas (indigenous, equity and diversity)

☐ Unit operations and processes

☐ Other: [N/A]

3.2. What were you hoping to change or where were you hoping to see an impact with this project? – *Please describe the intended benefits of the project for students, TAs, instructors and/or community members.*

Game theory is the mathematical study of strategic decision making, and is important in many fields, including economics, biology, politics, computer science, and mathematics. However, due to its mathematical nature, many of the concepts and insights it can provide are difficult to understand – particularly from a practical, hands-on, perspective.

We know from the extensive literature on the subject that experiential learning can give students concrete learning experiences, and improve comprehension of theoretical concepts. A proven method for providing these kinds of experiences in game theory is through the use of tools like games and experiments. However, existing tools and software are often too complex (e.g. requiring expert programming skills) to provide meaningful concrete experiences for most students in many courses. The challenge we faced was to develop learning experiences in these areas: this formed the basis for our project's objectives.

We were particularly interested in two concepts in the theory of repeated games: (i) strategies and (ii) the evolution of cooperation. The evolution of cooperation is a complex, theoretical, but widely applicable area of game theory taught in many disciplines. In the Axelrod "experiment", experts developed strategies to play a simple game against one another in an environment that rewards selfishness. Contrary to theoretical predictions, the best performing strategies were cooperative; a surprising result. Understanding the emergence and maintenance of cooperation is an objective of most courses which use game theory, as are the concepts that are built to explain it. Similarly, understanding what a "strategy" is in a complex environment such as a repeated game clarifies and demonstrates one of the most important principles of game theory.

We sought to develop a learning experience, based around a computer application, which would allow students to take part in a re-creation of Axelrod's tournament – but without the need for any complex tools. Preliminary pilot studies (in 2017/2018) demonstrated the utility of this approach, but without an application the logistical hurdles were too formidable for routine classroom use. We had several main goals:

- First, to develop and test the use of such an application for classroom instruction. We sought to use an open-source "visual" programming language called Blockly (similar to the commonly-used Scratch[3] but more flexible) to implement our application. This language let us create "blocks" specifically for game-specific environments – allowing us to separate the important pedagogical goals (game theory, concrete experiences) from the technical skills (logic, programming) which would otherwise be needed to implement them. This kind of software, which allows students to experience Axelrod's tournament without a background in programming did not currently exist; developing and learning how to develop such a tool was a core goal of our project.
- Second, to develop instructional materials to support reflective observation and a connection to the abstract concepts (game theory) being taught in the rest of the course. We wanted to place emphasis on encouraging and promoting peer-based learning, especially in groups where students have different background and strengths. In our approach, students work together to share their experiences and evaluate ideas surrounding cooperative games, and explore together the performance and development of their strategies. We also wanted to pair this with lesson plans and assessment, to allow instructors to easily adopt this as a complete "learning experience" into their course with minimal effort.
- Third, and finally, we wanted to develop experience and fluency with the Blockly framework among faculty and students here at UBC. The framework, which we are using for game theory, is highly flexible and could potentially be used in many other fields – such as language learning, mathematics, and simulation exercises. This pilot project would demonstrate the feasibility of other kinds of applications, and provide knowledge and advice for other individuals working on similar projects.

[3] Scratch.mit.edu. (2021). Scratch – Imagine, Program, Share. [online] Available at: https://scratch.mit.edu [Accessed 2021-04-28].

From a student perspective, the use of this tool was also intended to refresh and improve the teaching of what could be a very technical and dry area of game theory, especially for students with weaker mathematical or programming skills. This would increase engagement with the learning experience, while also increasing understanding of the core concepts and conclusions the Axelrod experiment describes.

3.3. Were these changes/impacts achieved? How do you know they occurred? – *How did you measure changes/impacts? (e.g. collected survey data, conducted focus groups/interviews, learning analytics, etc.) Describe what was learned from this process. You are encouraged to include copies of data collection tools (e.g. surveys and interview protocols) as well as graphical representations of data and/or scenarios or quotes to represent and illustrate key themes.*

Overall, we either met or exceeded our expectations for the different elements of the project. We evaluated our goals based on the outputs (for deliverables like the application and learning materials), or based on a series of surveys conducted in 2019/2020 and 2020/2021. We also, in the summer of 2019, conducted a small workshop to help aid in development of the project.

With respect to our first goal, the development of the Project AXLRD (as we call it) application went much better than we expected. In our original timeline, we estimated that a working ("beta") version would be completed for Fall 2020. However, through a combination of hiring appropriately skilled students and careful planning, it turned out that the Blockly framework was much easier to implement and develop than we had anticipated. We had a fully functional version by Summer 2019, and were able to iterate on the design and structure of the application rapidly over the two years of the project. Accordingly, in 2020/2021, we focused primarily on tutorials, bug-testing, user interface, and more advanced features of the application – which was fortunate, since user testing was hindered by the COVID-19 pandemic in this period. The current (as of 2021) version is displayed in Figure 1.

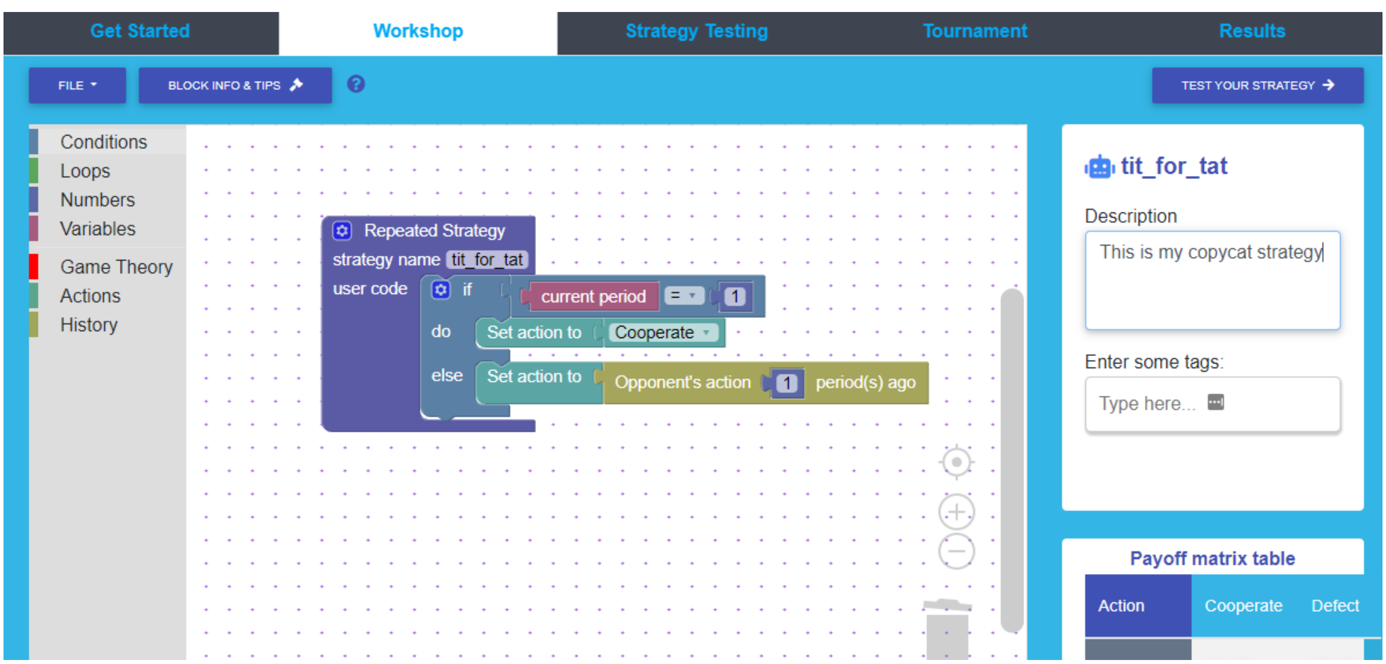

Figure 1 AXLRD Strategy Builder Tool

This also demonstrated that the Blockly framework is suitable for students and faculty with only minimal programming experience: we judge that intermediate familiarity with Javascript and computer programming is likely all that is necessary to develop an application using this framework. Deployment (for example, on a website) can be more complicated, but can be supported using assistance from learning technologists or other educational support staff with minimal additional effort.

We also developed a series of learning activities, and tested them in several classes during the 2020/2021 Semesters. These classrooms spanned a wide range of student levels (from 1st to 4th year), faculties (science, arts), and mathematical abilities. These activities included (i) lesson plans, (ii) slides, and (iii) assessments. We evaluated both the learning activities, and the Project AXLRD tool using a series of surveys.

For the purposes of this report, we consider three key measures from this survey: (a) was the tool easy to use, (b) did it make learning easier, and (c) did it make learning more fun. These capture most of the student experience metrics we intended to learn about in this project. This survey was administered to 330 second year arts students, taking a strategic thinking course who used the tool for one of their assignments.

You can see a distribution of the resources in Figures 2 and 3, below. Of these students, 67% (SE 2.5%) agreed that the project made learning easier; only 14.5% (SE 1.9%) disagreed. Even more positively, 74.2% (SE 2.4%) agreed that the project made learning more fun, with only 7.2% (SE 1.4%) disagreeing. We think that some of this difference comes from challenge of learning a new tool; while 59% (SE 2.7%) agreed the tool was easy to use, 22.4% (SE 2.3%) did not agree and found it challenging. This is an area in which we are actively working to make the tool simpler, and provide more guidance for students.

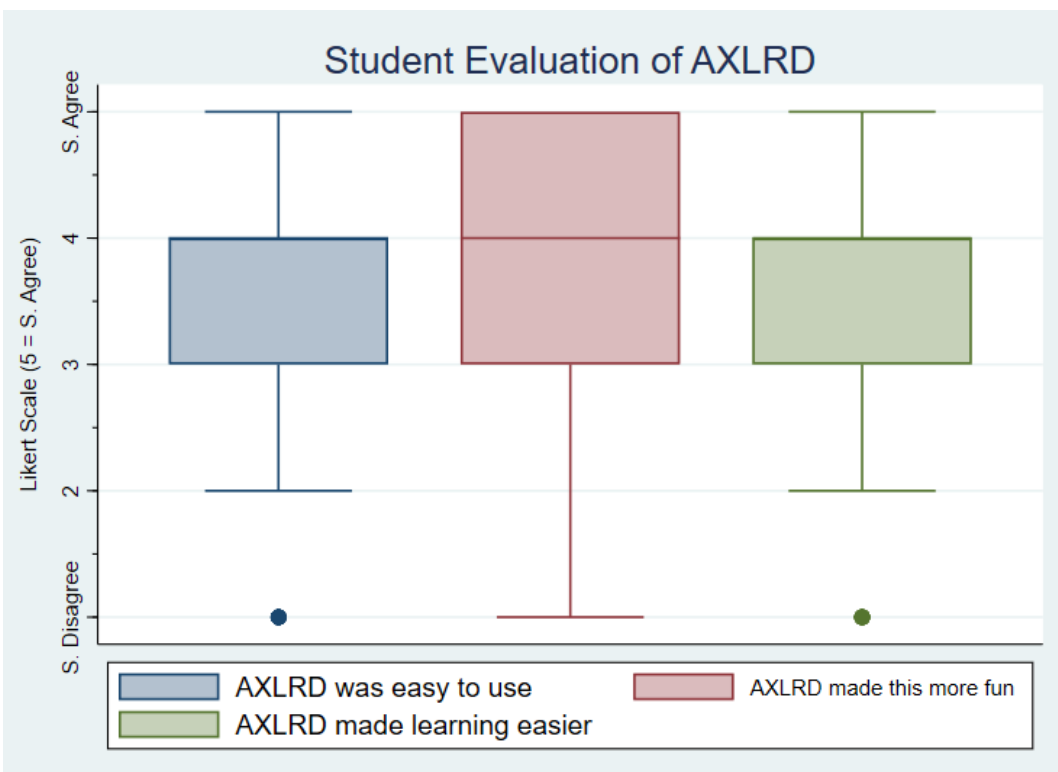

Figure 2 Student Evaluation of AXLRD

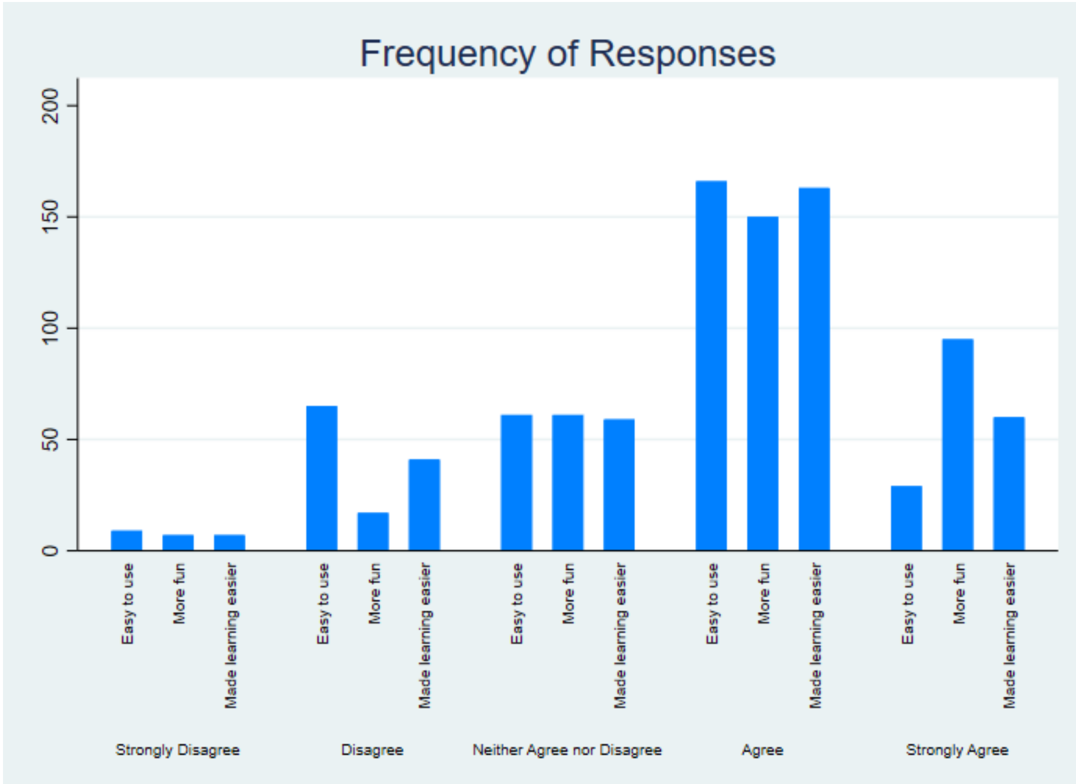

Figure 3 Distribution of Responses

3.4. Dissemination – *Please provide a list of* ***past*** *and* ***upcoming*** *scholarly activities (e.g. publications, presentations, invited talks, etc.) in which you or anyone from your team have shared information regarding this project. Be sure to include author names, presentation title, date, and presentation forum (e.g., journal, conference name, event).*

- Poster Session: "Experiential Learning in Game Theory." 2021 TLEF Virtual Showcase, Celebrate Learning Week, UBC-V, May 2021.
- Poster Session: "Interactive Simulations without Programming: Experiential Learning in Game Theory." EL Market, CTLT Spring Institute, UBC-V, May 2019. (link)
- Publication: "Experiential Learning in Game Theory." Working Paper.

4. TEACHING PRACTICES – *Please indicate if* ***your*** *teaching practices or those of* ***others*** *have changed as a result of your project. If so, in what ways. Do you see these changes as sustainable over time? Why or why not?*

This package has changed the way we teach and explain the theory of repeated games; it has also improved our approach to describing and explaining strategies and computational thinking. Previously, we taught these subjects very theoretically – using a combination of mathematical descriptions and analogies to provide intuition. This frequently left many students with gaps in their understanding, particularly where it was difficult to concretely express these mathematical and logical concepts using analogies. We also struggled significantly when helping students to understand the role beliefs play in making a strategy perform well – with many students misunderstanding the relationship of equilibrium and best response in complex environments.

With Project AXLRD, we now teach these significantly differently – emphasizing the conceptual relationship to the "big ideas[4]" of cooperation and strategic thinking. We ground theoretical analysis of strategies and behavior in practical, experience-based exercises which ask students to build and evaluate strategies. We also centralize and highlight the critical role beliefs and expectations play: having students explore, through trial and error, how different beliefs about how their opponents will play affects their strategic choices. This concept has significantly ameliorated the deficits we observed previously in terms of understanding equilibrium and best response.

Project AXLRD has also enabled us to introduce new students to strategic thinking. We've added a module to an introductory "Computational Thinking" course, which gives students an opportunity to apply programming techniques they've been learning and test their understanding in a (low-stakes) competitive environment. In doing so, they achieve several important learning goals:

- Use abstraction and decomposition to clarify and simplify the critical pieces of a problem;
- Choose appropriate models and representations to aid in solving the problem;
- Trace through code using sequences of instructions, variables, loops, lists and conditional statements in short programs;
- Describe in English what a block of code does; and
- Evaluate if a given code block correctly implements an algorithm.

We also believe there are significant benefits to be realized from peer-learning, especially in this environment. Students, by working in groups and sharing perspectives, come to a more complete understanding of the role of beliefs – since there is no objectively "correct" belief, different opinions and ideas all have objective value in developing strategies. This creates meaningful, assessment-oriented reason for students to deeply comprehend beliefs and their role in strategic thinking. We also note that student strategies developed with the Project AXLRD tool are significantly more complex than we expected, and that we observed when asked to develop strategies without the tool. This has provoked our interest in this phenomenon, both from an experimental economics and pedagogical perspective.

5. **PROJECT SUSTAINMENT** – *Please describe the sustainment strategy for the project components. How will this be sustained and potentially expanded (e.g. over the next five years). What challenges do you foresee for achieving the expected long-term impacts listed above?*

One of the biggest strengths of this project was the decision we made early-on to use public, open-source tools whenever possible, and manage the application development centrally. This has made sustainment straightforward: all of the application materials are stored in a centralized Git repository, and rely on standard Javascript libraries – making maintenance and on-going development easy. We plan to continue iterating and refining the Project AXLRD tools to address specific use-cases and correct any errors or ambiguities in the tool as they arise. The teaching resources are also complete, and do not require on-going development.

[4] See, for example: Mitchell, I., Keast, S., Panizzon, D., & Mitchell, J. (2017). Using 'big ideas' to enhance teaching and student learning. *Teachers and Teaching*, 23(5), 596-610.

We also plan to release all of this project, including the codebase and teaching resources, under an open-source license for future development and use outside of UBC. This will require some additional work to refactor the underlying code and provide implementation details – but does not require any specific resources, other than time from the PIs. We will likely seek additional funding to assist with this element of the project in the future from OER funding sources.