ISSN 2185-3762

Studies in Self-Access Learning Journal
http://sisaljournal.org

As If … A Game Theory Perspective on Self-Access Learning

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Publication date: September, 2019.

SiSAL Journal Vol. 10, No. 3, September 2019, 223-238

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Abstract

The applicability of game theory (Osborne, 2004) to the design and management of learning activities within a self-access learning center is discussed in relation to encouraging unmotivated students to engage more with autonomous study. Through discussion of some basic principles of game theory and how they might apply to self-access learning, a theoretical example is used to demonstrate how the costs and rewards of activities can be balanced using game theory in such a way as to encourage students to complete activities in order to foster autonomy and motivation. Further examples from game theory are provided to show how it can explain some of the counterintuitive results often seen in self-access learning at Japanese universities. Possible future quantification metrics are briefly discussed in relation to the human-capital and social-capital costs and payoffs involved in student use of self-access learning centers. A game theory perspective on self-access learning may offer the potential benefit of providing a quantitative model that might allow the application of artificial intelligence and a complex dynamic systems approach to student usage data.

Keywords: game theory, self-access learning, complex dynamic systems

Game theory is a branch of mathematics concerned with studying social phenomena *as if* they were games. Most famously it came to public attention in the Russel Crowe movie, “A Beautiful Mind” about John Nash whose work on Game theory earned him a share of the 1994 Nobel Memorial Prize in Economic Sciences. As such, it has found a multitude of uses in economics but has not seen much application in the world of education beyond the teaching of economics (Camerer, Ho, & Chong, 2004; Dixit, 2005) and its use in some International Relations and Strategic Defence Intelligence studies (Bier, Oliveros, & Samuelson, 2007; Bistarelli, Dall’Aglio, & Peretti, 2006; Hausken, 2002; O’Neill, 1994). However, there are some basic features of Game theory that make it highly suitable for use in analysing learner autonomy, student agency and self-access learning, especially if we consider learning as a complex dynamic system (Ellis & Larsen-Freeman, 2009).

It is necessary at this point to make clear that I am taking a theoretical ‘perspective’ rather than an ‘approach’ (Larsen-Freeman & Cameron, 2008). As in most complex dynamic systems, a thorough understanding of the internal mechanisms is absolutely necessary to adopt an empirical approach. Terms from complexity theory such as "attractor state" are powerful concepts in the natural sciences (Dörnyei, 2014; Larsen-Freeman & Cameron, 2008), but we cannot claim to have determined what they are in the social sciences from just a 'perspective', where we have a very limited understanding of the relationships between psychological schema, rather than an empirical 'approach', where we have detailed formula that have been found to govern the internal relationships of a system. In a social environment, such as a Self-Access Learning Centre (SALC), it is impossible to see the internal relationships between schema inside the minds of our students: we are not mind readers and we should not, even unintentionally, suggest that a particular perspective gives us a clear picture of student thinking. This is where we can start to apply Game theory. Game theory has been developed to try and compensate for missing information (McCain, 2003, pp. 3–6), particularly in non-cooperative games where the players are opponents and there are good reasons for concealing information (McEachern, 2017, pp. 13–20). The first step is to treat learning activities within an institution *as if* they were part of a game.

Cooperative and Non-cooperative Games

One of the principles of Game theory is that each social situation can be divided into two groups either cooperative games or non-cooperative games (McCain, 2003, p. 33). Thinking about learning and particularly self-access, the ideal situation is that learning is a cooperative game between the students and the teachers or learning advisors. The student uses their agency to express learner autonomy and the teacher or learning advisor facilitates the student's learning in a cooperative manner to achieve a positive end result.

However, reality is often far from ideal. Students may well see teachers and learning advisors initially as authority figures in an institutional setting, including SALCs. In Game theory, such authority figures might be seen as opponents in a non-cooperative game (Scharpf, 1994). The SALC from this perspective becomes a very different game model where the students are playing against the teachers with the objective of reducing their engagement with learning activities as much as possible. This might seem a very negative viewpoint to take of self-access learning, but assuming at least initially that a game model is non-cooperative is an important principle in Game theory (Basar & Olsder, 1999; Nash, 1951).

I hesitate to include the actual formula of things such as the Nash equilibrium here as a detailed understanding is not necessary, especially as we are adopting a perspective rather than an approach (see Pastine & Pastine, 2017 for a very accessible explanation of Game theory and Nash equilibria). The main thing we need to know as far as SALCs are concerned is that, according to Game theory, students will tend to choose their best response in a rational manner (McCain, 2003, p. 13). This best response is based on the total payoff (reward) for the student and not what we as educators may envision as their goals. Game theory tells us to imagine a situation, in this case the SALC, *as if* it were a game. So, we need to consider a balance between rewards for cooperative actions versus rewards for non-cooperative actions.

Initially, we want to encourage learner autonomy, so our initial action might be to make a SALC entirely voluntary. This encourages those students who are motivated to learn to act cooperatively with the teachers and learning advisors, but on the other hand, it might actually reward rational players who act non-cooperatively, or in this case, unmotivated students for not using the SALC. If they are playing a non-cooperative version of our SALC game (our *as if* it were a game model), then their objective is to reduce their intellectual engagement and effort as much as possible and making the SALC entirely voluntary would allow them to “win” big if we imagine them *as if* they were non-cooperative players rather than students.

Opportunity Costs, Payoffs and SALC Legitimacy

To better understand how we might apply Game Theory to SALCs, we have to conceptualize costs and payoffs in a more social rather than financial way. In the Game theory literature, the costs of playing a game and the potential benefits, the opportunity cost and the payoffs in economics terms, are usually some financial or monetary amount (McCain, 2003; McEachern, 2017, pp. 1–5). For Self-Access Learning, this is not a very satisfactory metric. University students are usually paying fees as few governments are willing to pay for tertiary education, but such fees are not a good way to understand the costs and payoffs for a SALC that may only account for a tiny proportion of those fees.

The most obvious alternative metric of time and effort is very common in teacher and education circles (Schilling & Schilling, 1999; Trautwein, 2007) but can lead to accusations of laziness on the part of students. Teachers might be able to guess how much time and effort is required by a set task and label students as hardworking or lazy depending on the actual time spent, but it is still a guess. While that label might be well deserved in some cases, there is a danger that such a label might prevent us from encouraging cooperative action in our SALC game model. We as language teachers do not know how much effort students might be expending in other areas of their lives. My current teaching context is at a university in Japan, and most Japanese students have either a lot of club responsibilities or part-time jobs (Asaoka et al., 2010; Danh Nguyen, Yoshinari, & Shigeji, 2005), and a few may even be carers or have other similar responsibilities at home. It is also possible that some otherwise hardworking students do not consider language study to be compatible with their main future and career goals (Apple, Da Silva, & Fellner, 2013). I do not believe these potential factors are exclusively confined to Japanese university students and should be considered by each teacher within their own context.

Thus, while time and effort are potentially useful metrics, we need to add another factor to account for the social costs and payoffs as well as considering motivational factors. It may be better to combine these metrics into two metrics, human capital and social capital (Banfield, 2015; Bourdieu, 2013; Coleman, 1988; Lin, 1999; Siisiainen, 2003). Human capital might cover the costs of both the time and effort needed to engage in self-access learning as well as the potentially unseen costs associated with the other parts of a student's daily and family responsibilities. Social capital could be used as a metric for the gains and losses associated with the social aspects of a SALC, such as interactions with other students, workshops or social events (see Lebaron, 2009 for a discussion of how Bourdieu quantified social capital and habitus). Conversely the costs of a SALC to a student's social life such as missing opportunities to hang out with friends or spend more time on club activities might be quantified in the same manner. Ideally, students will gain some social capital from attending social events within a SALC, but we can recognize that social capital may be lost by forcing non-cooperative players to engage with learning activities. Unfortunately, for those unmotivated students, school and by extension university may never be cool enough to convey social capital.

Social capital may also be a useful metric to consider the legitimacy of a SALC (Maton, 2013a). A SALC that has the full support of both language and non-language teachers will be seen as having more legitimacy by the students and a much more attractive source of social capital – a major payoff in our SALC game. This is especially so if the senior professors and staff are seen to associate with the SALC. Using the idea of knowledge specialization codes from Legitimation Coding Theory (LCT) (Maton, 2013b), it could be argued that the attendance of senior professors from across different fields at SALC events conveys legitimacy through increased social relations and epistemic relations (an elite knowledge code) and increases the social capital available to students (Edsall, 2018). It may also be possible to measure this social legitimacy quantitatively using systemic functional linguistics and LCT (Christie & Maton, 2011) to look at the specific language used to convey this legitimacy from professors to students. In my own experience of two SALCs at different universities, Science majors are much more likely to use a SALC when their science professors endorse it as having recognized value in their own specialist field – we need to address students' ideal selves and not just their ideal L2 selves (Ushioda, 2011). Encouraging graduate students to seek help with writing and presentations from a SALC's learning advisors and staff may also have a beneficial impact as students see their seniors (sempai) using the SALC, which can only increase the perceived payoff for rational players.

However, if a SALC is seen as belonging to only a small group of cooperatively acting rational players, such as only English majors or only foreign exchange students, then the amount of social capital to be gained is dependent on the identity of the student. The legitimacy of a SALC can suffer in this case, where the SALC game is distorted based on student identity and the amount of social capital available as a payoff is seen as being dependent on the identity of the player (see Ushioda, 2011 for a discussion of motivation and identity). The dependence of a game on identity – we could understand this as the 'fairness' is referred to as 'symmetry'. Symmetry is an important concept in game theory, and it is important to consider if we are to apply game theory to self-access learning.

Symmetric and Asymmetric Games

In game theory, a symmetric game is one where the payoff for playing a particular strategy is independent of the character or identity of the person playing (Abreu, Pearce, & Stacchetti, 1993; Schelling, 1959). The payoff for a symmetric game depends on the strategies available and not on the individuals playing the game. We can see that in an ideal world a SALC would be a symmetric game because we want our SALC to be fair and equally accessible to everyone in the student body. Also, from a long-term perspective, we want the SALC to have some longevity and not require a complete renewal every time new students join the university. However, we have to accept that we are much more likely to have an asymmetric game where the payoffs for using the SALC vary a lot for each individual. Events and social activities in particular are going to have different costs and payoffs for different students. We can reduce the effect of this within our game if we consider how to diversify the strategies available to students without privileging one particular strategy over another. By privileging one strategy over another or making a particular SALC activity more important, we can privilege those who have more natural talent in a particular skill area, so making the game asymmetric and deterring less able students who start to see the SALC game as being biased towards specific talented people rather than promoting learning.

The perception that a SALC somehow belongs to a small subset of students could be very problematic (Ushioda, 2011 explains the significance of identity to language learning motivation). The result can be to demotivate students and turn cooperative actions into non-cooperative actions, where students try to actively avoid engagement with the SALC. This can be even worse if the perception of the payoffs for any learning activity compares unfavourably with the perception of the costs of doing the activity. We have to consider whether our SALC game is seen as providing payoffs to all players or only the 'winners'.

Zero-Sum and Non-Zero-Sum Games

For unmotivated students, a SALC may very well appear to be a Zero-sum game (Kuhn & Tucker, 1953; Miyasawa, 1961; Morrow, 1994), meaning that the students' opportunity costs in the form of loss of time and effort – their human capital spent on activities, pays for the teachers' winnings in making recalcitrant students use the SALC and study English. In Zero-sum games, the winners are always compensated by the losers and there is no appreciable gain across the system. An even worse situation would be a Negative-Sum game where nobody gains anything. Both of these would result in non-cooperative versions of the SALC game and should be assumed as a baseline to work from even if it initially appears to be a very negative viewpoint.

The goal then in a SALC is to encourage and manage the game so that the game can be seen as a Non-Zero-Sum game, where everyone benefits. When there is cooperation action in a non-cooperative game, where the students and SALC staff work in unison, this might be quite straightforward as everybody acts to increase the learning of the students. When there is non-cooperative action in a non-cooperative game model, this is more difficult. Unmotivated students see the SALC game as just extra study without any beneficial learning as payoff. However, the biggest danger is not that unmotivated students see the SALC as a Zero-Sum game, but that the teachers and support staff see it as a Zero-Sum or Negative-Sum game where the costs to teachers is far more than the payoffs achieved (and everyone loses in the case of a Negative-Sum game). It is important then to manage the SALC such that costs to both the teachers and students are reduced and the payoffs are increased.

Visualizing Payoffs – A Theoretical Example

Using game theory, we can visualize a SALC activity in terms of the rewards or payoffs for particular strategies that players or students might employ. Let's imagine that the SALC has been made voluntary, but that extra credit can be gained from doing a variety of learning activities. For simplicity, we shall assume that the extra credit SALC activities have been set up to be done by individuals and the extra credit is given to individual students who submit some proof of completing the activity, such as a completed comprehension quiz. If we take such a notional Activity X and assign arbitrary values for the activity, say 10 for the payoff and 6 for the cost, assuming that this is a reasonably challenging activity in that it requires mental effort and some time to complete. For the individual student, this would give us a payoff matrix (known as the dilemma matrix (McCain, 2003, p. 11)) of our game as follows:

Table 1

Theoretical Student Payoffs for Activity X for 1 Player

	Total Payoffs = Payoff - Cost
Completes Activity X	4
Does NOT Complete Activity X	6

The total payoff for not doing Activity X is zero minus a negative amount of effort (the student actively spends no human or social capital), so it is actually a positive number. We can see from this that while completion of the Activity X might be very worthwhile, if we assume that our student is a rational player, then he or she is unlikely to complete the activity, and it is quite possible that the student will not even attempt it. Not attempting the activity is their best response. Assuming that for some reason the student completes the activity, then he or she will be less likely to attempt a second Activity Y as any rational player will evaluate the time and effort (human capital), as well as the social capital, spent on doing the activity. From this, we can see that we need to address the balance of payoff to cost if we are to convince rational players to participate in SALC activities – it is not enough to just create activities that motivated students will find interesting. We can avoid this situation by providing a diversity of different activities that require different types and amounts of mental engagement (Cotterall, 2000; Cotterall & Crabbe, 1999; Lee, 1998).

Of course, students are very rarely studying in isolation and many students will visit the SALC for the first time with a friend or classmate. Let's take the same activity X, but let us assume that two students, Kintaro & Gintaro complete the activity together. Again, we shall assume that they are rational players who are only playing our SALC game because they need the extra credit to avoid failing or because they need to complete one or more activities as part of a mandatory SALC orientation. We can use the dilemma matrix to visualize this slightly changed game as follows:

Table 2

Theoretical Student Payoffs for Activity X with 2 Players

		Gintaro	
		No attempt	Completes Activity
Kintaro	No attempt	6, 6	8, 4
	Completes Activity	4, 8	7, 7

In this SALC game, if they look at Activity X and both decide not to do it, then they both gain by not spending any time and effort on the activity, shown as "6, 6" in the grid. If they both do the activity together, the cost of 6 is shared while the payoff is given individually, so they both gain "7, 7" as shown in the bottom right of the column. However, if Kintaro does the activity and Gintaro copies the answers for the quiz to prove he did the activity, then Kintaro only gains 4, while Gintaro gains 8. Gintaro does not receive the full reward because freeriding comes at some social capital cost – freeriding is not usually socially acceptable. Assuming a symmetric game, this is similar if the roles are switched and Gintaro does the work and Kintaro copies. We can see that if a learner advisor were to step in and force the students to do the activity on an individual basis, then the game would return to the same form as in Table 1. This tells us that Activity X might actually be better as a shared activity, because the high cost can be shared between two or more students making it more likely that both Kintaro and Gintaro attempt the activity.

In this simplified form, the SALC game of Activity X resembles the "Prisoners' Dilemma" in economics (Axelrod, 1980; Kuhn & Tucker, 1953; McCain, 2003, p. 9; Rapoport, Chammah, & Orwant, 1965), where two prisoners have to choose to confess or not confess and their payoff depends on whether the other prisoner also confesses or not. The options available are contingent on what the other player does giving a "If-then" logic where every action can be evaluated as being contingent on some other action.

What game theory tells us about the prisoners' dilemma and similar games is that the most probable strategy – the best response depends on how many turns or rounds the game has (Axelrod, 1987; Nowak & Sigmund, 1993). If Table 2 is perceived to be the only round, then players will tend to try and freeride by copying their friend's answers. Gintaro can see that if he waits for Kintaro to do the activity, then he does not need to do much work, and his gain is greater. However, Kintaro has the same information and the same non-cooperative approach (a required initial assumption of game theory), so assuming they only play the SALC game once, the most likely result is actually that neither student attempts the activity. This result will change if this is not the only round of the game and further attempts at play are possible.

One of the more useful aspects of game theory is the finding that the perception of past and future rounds of a game can have a big impact on how our SALC game will develop and the strategies that players are more likely to use (Nowak & Sigmund, 1998). Returning to our SALC activity, Gintaro can choose to copy Kintaro's answers and freeride, but this will most likely affect Kintaro's choice in the next game. Kintaro is less likely to let Gintaro cheat in the next round if Gintaro copies his work in a previous round. This leads to the situation in a two round game where players will tend to cooperate in at least the first round, so in our game both Kintaro and Gintaro would work together to complete Activity X, but the strategy of tending to freeride will become their best response in the last round. This could be used to explain why many SALCs see a surge in use within the first few months of each academic year that then tails off: students get tired of working with apparent freerideers – classmates who just copy. In our theoretical example, Kintaro gets tired of Gintaro copying his work and chooses to either stop attending the SALC or start doing the activities by himself.

If we extend this model to a multi-round game where the last round is perceived to be very distant, then the best response can shift to sustaining cooperative action where Kintaro and Gintaro both do the activity together. This suggests that one aim of SALC staff should be to keep the same students coming back into the SALC. If familiarity and routine reduce both the human and social capital costs of SALC activities, then cooperative action is more likely. Further, if Kintaro gets a large payoff of increased ability over the long term from becoming a regular at the SALC, he may choose to continue doing activities and putting up with Gintaro, but there is also the possibility that increased motivation may lead him to take cooperative actions making it a win-win situation for both Kintaro and the SALC staff. That is assuming that there is a payoff for the SALC staff from increased student participation. This would change the nature of our SALC game and make the played strategies more likely to be cooperative, but potentially more asymmetric as the payoffs would be different for our cooperative player, Kintaro and our still uncooperative player, Gintaro.

However, in a multi-round SALC game, they could also shift to a tendency where they both do not complete any further activities if the perceived benefits are not high enough compared to the associated costs. This means that from a game theory perspective, we have to consider balancing the payoffs and costs of an activity within a SALC when creating that activity. Given the potential number of players involved in our SALC game, we need to plan out a variety of activities that can address a multitude of acceptable costs and try to match first-time students to an activity that has sufficient reward but not such a high cost as to deter them from coming back a second time.

Mechanism Design and Benevolent Authority

This balancing of costs and rewards is the main principle of the Nash Equilibrium and other game theory solutions (McCain, 2003, pp. 225–226), where the best payoffs are achieved with the least costs as a response to the other players – the teachers, staff and other students in our SALC game. Mechanism design comes from assuming that the desired result is achieved and attempting to change the rules of the game in order to achieve that desired result (McCain, 2003, pp. 286–298). In the context of a SALC, the design of activities could be changed to encourage more students to complete the activities, such as changing theoretical example, Activity X above so that it can be completed by two students in a team. This could be achieved by assuming that all students are non-cooperative players and adjusting the rules and rewards appropriately using past data on the completion of activities within the SALC. It can also be achieved through eliciting feedback from students through surveys and interviews, as well as appropriate inducements (Faltings, Radanovic, Brachman, & Stone, 2017) and analysing the diversity of ways in which students completed the activities (or cheated) in reality.

One warning from game theory on this topic is extremely pertinent to activities within a SALC. The warning comes from analysing the actions of authority figures and the penalties they impose on negative strategies that subordinates or players choose (Buchanan, 2001; Hawthorne, 1975). Authority figures are often treated as umpires who do not participate within a game, but game theory researchers have argued that in reality such authority figures, particularly in the world of economics, should be treated as a third player in the game, especially if they are able to apply discretion and flexibility in a way that is benevolent to the players (McCain, 2003, pp. 295–297). In my personal experience, benevolent flexibility is potentially very common amongst teachers at Japanese universities as we all want our students to do well. This benevolent flexibility may actually lead rational players, or unmotivated students in our non-cooperative SALC game model, to choose not to complete activities ignoring whatever penalties are in place to prevent such a choice of strategy. This is because the penalties involved reduce the payoff to the authority figure or teacher in the form of students engaging meaningfully with the SALC activities: the teacher is benevolent, so penalizing the students also has a negative impact on the teacher, resulting in the teacher not penalizing the students next time. The legitimacy of those penalties is then completely lost. Thus, more penalties might actually mean fewer student in the SALC. The key to avoiding this situation may be to reduce the impact on the individual teacher of any penalties imposed on rational students, which may in turn also mean reducing penalties on the students and instead focusing on rewarding students for playing our SALC game cooperatively. However, this application of game theory's Benevolent Authority Paradox (McCain, 2003, p. 293) remains somewhat unclear as penalties play an important function in many schools and universities. Balancing the impacts of penalties and rewards might be more easily achieved if we can quantify usage data in such a way that we can begin to apply the mathematics of Game Theory to SALCs.

Quantifying a Possible Future Approach

At the beginning of this article, I made clear that this article was specifically taking a game theory perspective rather than a mathematical approach to analysing Self-Access Language Learning in a Japanese university setting. This article cannot claim to provide a bridge between the incomplete information available to teachers and staff in a SALC and mathematical approaches such as a complex dynamic systems approach. However, it does outline how it may be possible to quantify and mathematically model activities within a SALC in order to encourage learners to engage more with language learning. In the future, it may also be possible to apply Artificial Intelligence techniques in combination with Game Theory to optimize student usage of a SALC and attendance at SALC events. To address this goal there are a number of questions that need to be explored.

One of the most important is how both human capital and social capital can be quantified (e.g. Lebaron, 2009). Recent commercial attempts to quantify these two concepts in social media have proved problematic (Cadwalladr & Graham-Harrison, 2018). Attempts to quantify psychosocial phenomena associated with these theoretical concepts for commercial and political profit have resulted in the misuse of data from social networking entities, such as Facebook and Google, and massive breaches of data privacy rules (Cadwalladr & Graham-Harrison, 2018). However, within a university setting and assuming that data is properly anonymized and only handled in-house following appropriate data privacy guidelines, then there is potential to increase the effectiveness of any SALC in encouraging learner engagement.

Even without the use of AI, Game Theory can be used to inform the design of activities in such a way as to encourage learner engagement and discourage cheating or avoidance behaviours using arbitrary values for human and social capital. By analysing the potential outcomes of SALC activities and their associated payoffs, those activities can be adjusted to optimize student engagement after several iterations. It can also be used to analyse how the culture developed within a SALC can help or hinder the goals of self-access learning, providing support for decision making and policy planning in both the SALC and the wider university setting.

There are limits to how game theory can be applied quantitatively to Self-Access Learning in that it requires an initial first approximation that can introduce errors (Molodtsov, 1999), but these relate more to the availability of sufficient computer and staff resources to provide an adequate quantification of the activities within a SALC and the ability of current staff to apply mathematical probabilities within game theory. While many language teachers working in SALCs recognize the power of mathematics and particularly the power of quantitative statistics, there is a tendency to either embrace statistical approaches at the expense of common-sensical truth (Scott, 2007) or to run away screaming. Mathematics is just another language. It has some very powerful real world uses and it has some limitations of which we need to be aware. However, game theory has much to commend it as a potential tool in providing a model for student participation in self-access learning, especially in how it can handle unknown variables. Further exploration of this approach to handling the incomplete data available to SALC teachers and staff may provide some very useful insights.

Notes on the Contributor

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Acknowledgements

The author would like to acknowledge the help and assistance of Mizuka Tsukamoto and Yoshitaka Seto in proofreading and critiquing this manuscript and providing a large amount of feedback. The author would also like to thank Dr. Ai Takeuchi for her critique of the article and advice on game theory, its terminology, and specifically the prisoners' dilemma. Any errors that remain belong in their entirety to the author.

This research report does not reflect the views of either Ritsumeikan University or UCL Institute of Education.

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