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Play in Scientific and Mathematical Non-Formal Education. Bagh Chal, a Tigers-and-Goats Game

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Abstract

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This work introduces the Playful Projects-based methodology, created with the aim of contributing to scientific and mathematic literacy from the STEM education perspective by means of work plans designed around traditional world board games. This methodology adapts that of Ethnomathematical Projects to non-formal educational contexts, building upon games as sociocultural objects of interest and play as a learning facilitator. Here, a summary of the first Playful Project designed around the Nepali board game *bagh chal* is presented. This is a bipersonal, zero-sum, complete and perfect information game. This Playful Project will be implemented in two middle schools in Granada, Spain. Students will learn the game and acquire certain knowledge about it by formulating hypotheses, validating or refuting them, making deductions, and drawing conclusions. In addition to the development of the characteristic skills of STEM disciplines, our proposal is meant to foster interculturality, inclusion, and playful as well as dialogic learning.

Keywords: Scientific education; mathematical education; STEM education; playful learning; world board games; non-formal education.

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1. Introduction

Here, we interpret scientific, mathematical, and technological literacy within the scope of educational action in order to achieve the maximum development and the best possible performance in each person's life as well as in democratic participation and citizenship. As expressed by Acevedo (2004, pp. 12-13), this aim of scientific education "must be addressed to contributing to citizenship education above all".

To achieve this literacy requires facilitating scientific learning and stimulating students' interest in sciences (Esteban, 2003). Science contextualization proves necessary in this task, thus addressing socially relevant scientific topics in teaching, in addition to hypothesis formulation, observation, data interpretation, and decision making (Esteban, 2003). Sanmartí and Marchán (2015) indicate that a scientifically competent student is a student who can reflectively engage in matters related to science and the ideas of science. This approach influences not only which sciences and which mathematics are to be taught, but also how these disciplines are to be taught.

Bergen (2009) considers it necessary to encourage playful behaviour and to educate through play in order to develop STEM disciplines (sciences, technology, engineering, and mathematics) and STEM-related skills. The underlying idea is that the enquiry and reasoning of scientists and mathematicians resembles children's way of thinking when playing meaningfully.

Through adequately planned educational activities, play stimulates cognitive, emotional, and communicative development while fomenting meaningful learning, all of which are essential aspects in the construction of social knowledge (Melo & Hernández, 2014). More specifically, formal games (games with rules) foster important skills needed in STEM disciplines, such as: creativity; meaningful and complex problems solving (Barab & Landa, 1997), spatial thinking (Newcombe, 2010); hypothesis formulation and argumentation; scientific approach to answering questions and drawing scientific conclusions (Sanmartí & Marchán, 2015); enquiry and autonomy; innovation; interpretation; mathematical modelling and analogy.

Furthermore, scientific and mathematical education extended to the sociocultural sphere, as in non-formal contexts such as hands-on museums, toy libraries, science clubs, fairs and workshops, is believed to lead to long-lasting achievements. Non-formal education relieves curriculum pressure, fostering a holistic, cross-curricular, interdisciplinary approach.

Playful activities require resources that permit the development of play idiosyncrasy. To generate these, we advocate the use of games that can serve as educational resources in both the formal and the non-formal context (Fernández-Oliveras & Oliveras, 2014a). More specifically, we deem the use of traditional strategy games as particularly valuable for scientific and mathematical education in non-formal contexts. Williford (1992, p. 98) states that these games are "attractive vehicles for enhancing general mathematical-reasoning skills". Precisely, an educational environment organized around games stimulates positive attitudes towards learning among students, and facilitates cognitive achievement, as revealed by conceptions of future teachers in training (Fernández-Oliveras & Oliveras, 2014b, 2015). In this sense, Ferguson (1995) reported improvements in multiple scientific and mathematical thinking-related skills through educational chess: abstract reasoning, strategic planning, evaluation and synthesis, critical thinking, problem solving, decision making, creativity, and flexibility. Wan et al.

(2011) have shown that professional *shogi* players' apparently intuitive performance comes from an enhanced pattern-recognition skill developed by experience and deliberate practice.

Similarly, we can assume that other similar strategy games may offer comparable benefits. Two fundamental processes take place in these games: 1) mental construction of the *game tree*, in which players use short-term memory, visuospatial skills, logical relations, heuristic strategies, analogy, and modelling; 2) *best-next-move* selection, where players use pattern recognition, logical relations, long-term memory, goal-based decisions, option evaluation, and decision making.

In the words of Melo and Hernández (2014),

> Recognition of play as an essential function of human knowledge evolution and development, and therefore of education, is fundamental, as to establishing its true pedagogical value and recognising its merits in every dimension of the individual development. (p. 42)

Non-formal contexts, which encourage active participation of students of any age, allow enquiry-based approaches. These require dedicating long time allotments to experiencing and reflecting on activities, which may prove difficult to find in formal schooling. Moreover, participation in extracurricular activities stimulates personal development during adolescence and early adulthood (Eccles & Templeton, 2002; Eccles, Barber, Stone & Hunt, 2003; Mahoney, 2000). These activities foster both peer relationships and relationships with adults, facilitate the formation of positive identities (Eccles et al., 2003), stir motivation and leadership (Eccles & Templeton, 2002). This is the approach we adopt in the experience presented in this work.

2. Objectives

We consider that some zero-sum[1], complete[2] and perfect information[3] strategy games, such as chess, can offer comparable benefits to those derived from it (Ferguson, 1995). This is the basis of our proposal, for which the objectives are:

- General objectives:
  1. Contributing to scientific and mathematical literacy in a non-formal educational context, fostering scientific, mathematical and cross-curricular competences development through traditional world board games-based work.
  2. Fostering interculturality, inclusion and dialogue as fundamental bases for personal relationships and scientific learning in multicultural contexts.
- Specific objectives:
  1. Practicing some world board games as samples of activation of scientific and mathematical thinking implicit in specific cultural contexts.
  2. Explicitly stating modelled features of scientific and mathematical thinking immerse in the games practiced.

[1] A zero-sum non-cooperative game is one in which the victory (gain) or defeat (loss) of a player equally and complementarily matches the defeat (loss) or victory (gain) of the other players.
[2] A complete information game is one in which every player is aware of the rewards and strategies available to other players.
[3] A perfect information game is one in which every player is aware of all previously occurred events and decisions.

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3. Collecting evidence of scientific and mathematically-inspired thinking in the approach of games by participant players.
4. Validating our approach of world board games-based educational proposal.
5. Fostering playful culture, analysing and promoting educational values inherent to practiced games.
6. Divulging some world board games as specific cultures' heritage reflecting on their cosmogonies, thus developing sociocultural knowledge.

3. Methodology

The proposal is structured around the teaching methodology of Ethnomathematical Microprojects created by Oliveras (2005, 2008). Microprojects are open interdisciplinary work plans, designed around a sociocultural object of interest, seeking the active and responsible participation of students in the construction of interdisciplinary contextualized meanings, especially regarding scientific and mathematical learning, and promoting a truly intercultural education. We have adapted this methodology to the study of games as ethnomathematical sociocultural objects, creating what we here term Playful Projects.

These Playful Projects are sequences of learning, communication, and reflective action activities constructed around a game, and they encompass a wide variety of sociocultural, scientific, and mathematical aspects. They are specially addressed to non-formal educational contexts. From a games theory perspective, the games considered are bipersonal, zero-sum, complete and perfect information games; from a cultural anthropology standpoint, they are world strategy board games.

An enquiry experience will be conducted in two educational centres in Granada, Spain, during the third trimester of the academic course 2015-2016 to pursue the objectives stated above.

As shown in **Figure 1**, this experience is divided into three phases. Phase 1, initial semi-structured questionnaire, is meant to assess personal playful and gaming background of participants as well as playful environment provided in their educational centre. In phase 2, Playful Projects are implemented, with participant observation and discussion groups. Finally, in Phase 3, questionnaires are administered to analyse: development of scientific and mathematical thinking as well as other cross-curricular skills (semi-structured), level of satisfaction, planning, and general development of the experience. Optionally conducted interviews aim to further deepen insights.

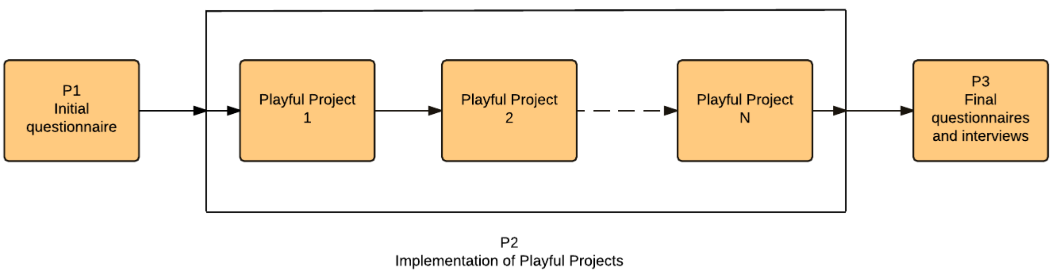


Figure 1. Structure of Playful Projects-based experience

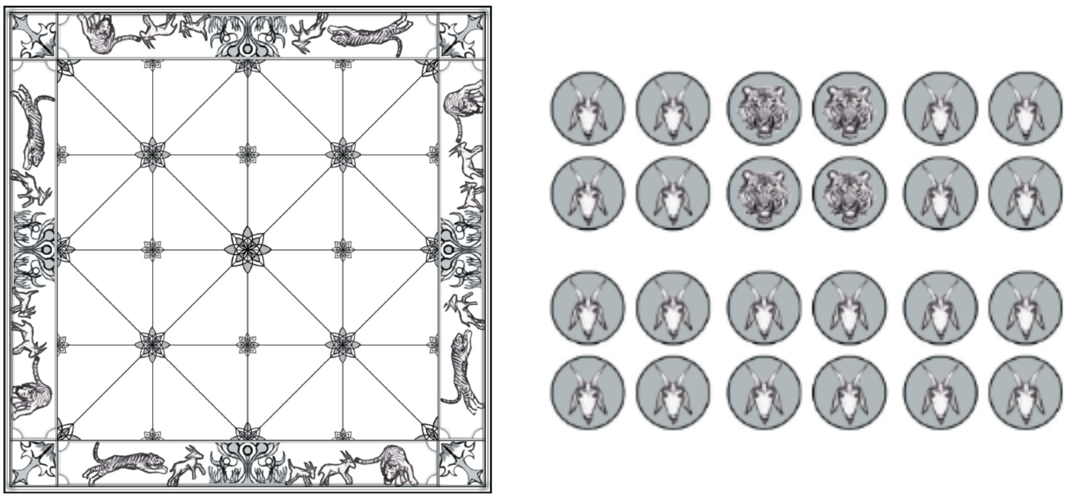
Within Phase 2, Playful Projects follow a structure begun with the study of the game under consideration as an ethnomathematical sociocultural object, from which specific aspects relevant to STEM education emerge. This study is conducted in accordance with three categories taken from Huxley's (1955) concept of culture: artifact, mentifact, and socifact. Activities specifically designed around the game to encourage scientific and mathematical thinking follow, presented in teaching itineraries corresponding to the participants' educational level.

Playful Projects are conducted in one-hour sessions in which the research team encourages player enquiries, registers relevant observations, and makes audiovisual recordings.

In this work, we summarize the first Playful Projects to be implemented, entitled "Bagh Chal, a Tigers-and-Goats Game". The game bagh chal was selected from a previously prepared list of games of interest (Gutiérrez-Perera, Fernández-Oliveras & Oliveras, 2015) for its potential in scientific and mathematical education.

4. Playful Project "Bagh Chal, a Tigers-and-Goats Game"

4.1. The game-artifact. Modelling game components



(a) (b)

Figure 2. Decorated board game (a) and representation of pieces (b)
(Source: Eckerd, S., http://boardgamegeek.com/filepage/72682/uncolored-print-n-play-bagh-chal-goats-and-tigers)

The game takes place on a square board (**Figure 2**, a) with 24 pieces, 20 of which represent goats and the remaining 4 represent tigers (**Figure 2**, b).

4.1.1. Geometric characterization and construction of the board

The board is formed by two groups of parallel lines – five horizontals and five verticals, intersecting in a 5x5 point grid, and six diagonal lines as shown in **Figure 3**. The pieces are positioned at the intersection points during the game, and not at the triangular areas delimited by lines.

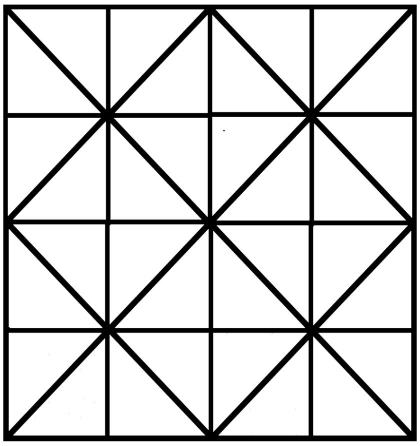


Figure 3. Geometric layout of the board

Figure 4 shows three distinct procedures for constructing the board, all of which can be completed freehand, using a straightedge and compass, or with software such as GeoGebra. Due to space restrictions, we cannot include the algorithmic descriptions of the constructions.

4.1.2. Technological construction of the pieces and the board

The abstract nature of the game is manifested in the fact that it is traditionally played on boards excavated or drawn on the ground, using pebbles, little sticks or cattle excrement for pieces. Manufactured boards are usually made of brass or wood, with a size of between 20 and 30 cm per side, and pieces tend to be made of brass, wood, resin or plastic.

Any set of pieces can be used, provided that players agree upon its representation. The 20 pieces representing goats must be equal to one another, and different from the 4 pieces representing tigers, which in turn must be equal to one another. Shape is not important, as the game can be played in an abstract fashion, as long as the size of the pieces is adequate in relation to that of the board and the hands of the players, and the pieces have a flat side which can lie on the board. We suggest using recycled or waste materials (e.g. caps, corks, clothes-pegs), beans, chickpeas, coins or coloured pieces of glass. If figurative pieces are preferred, we recommend making these out of handicraft materials such as clay, modelling clay, air-dried plaster, recycled paper, etc.

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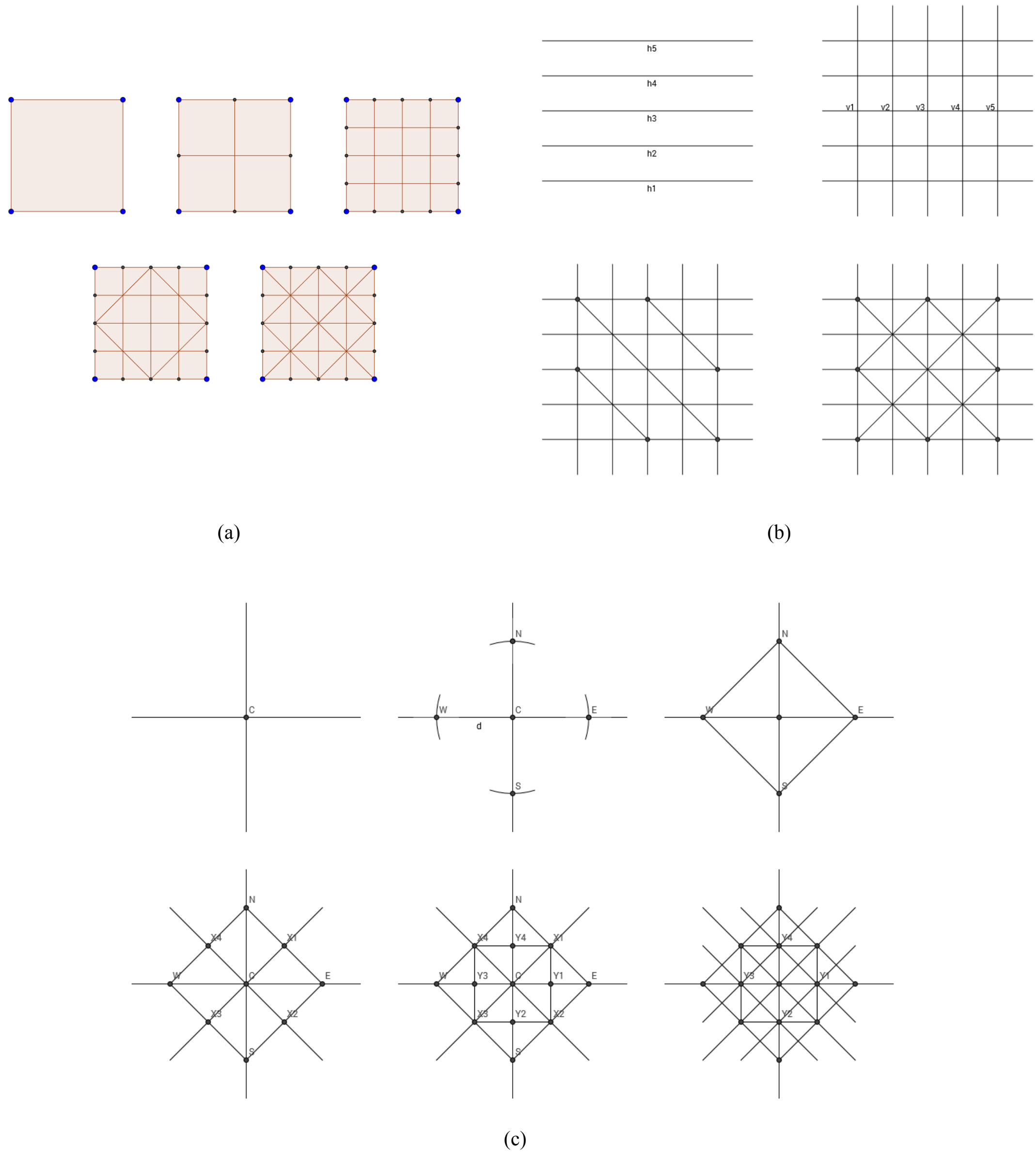

Figure 4. Three different board-construction procedures

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4.2. The game-mentifact. Game classification, rules, strategies

4.2.1. Game classification

According to mathematical games theory (Leyton-Brown & Shoham, 2008; Shoham & Leyton-Brown, 2010), bagh chal is a bipersonal (it involves two players), finite (regarding the number of available strategies or choices), dynamic (players do not simultaneously decide their strategies), sequential (players alternate turns), non-cooperative (players compete and cannot win or lose together), zero-sum, complete and perfect information game.

According to Ballesteros (2005), whose classification is based on the game objective and the type of strategy employed to pursue it, bagh chal belongs to the family of *tafl* games, since it involves two unequal opposing forces which try to capture the other player's pieces.

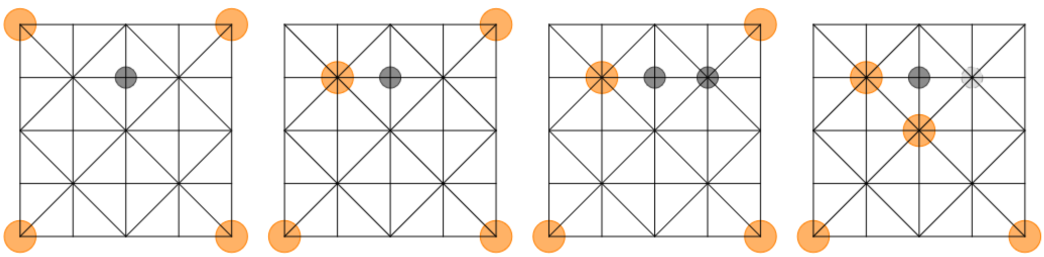
Other authors (Gutiérrez-Perera, 2014, p.33), considering the symbolic aspects, classify it as a hunting game, since it involves a confrontation between animal predators and prey, which is idiosyncratic of the game's cultural context. The two forces have "different objectives and even different movement rules": specifically, prey cannot capture, a distinctive factor in contrast to war games, in which both forces can capture the opponent's pieces.

4.2.2. Game rules

One player controls four tigers, initially placed on the board corners. The other player controls 20 goats, initially placed outside of the board. For the tigers, the objective is to capture five goats, while the goats must completely block all of the tigers' legal moves. The goats start the game.

The game takes place in two different phases. During the first phase, goats are placed, one per turn, on any free intersection point; they cannot be moved. Tigers move, one per turn, to a free adjacent intersection point along a line. A tiger can capture an adjacent goat if it can jump over it onto a free intersection point on the other side, as long as the three points (origin, goat-occupied, and destination) are aligned and interconnected. A tiger cannot jump over two goats, change jump direction in mid-air, or make more than one capture in one turn. Capturing is not mandatory.

Figure 5 shows one possible opening sequence from the game start, up to the conclusion of the fourth turn. See a goat being captured in the tigers' second turn, after a forced mistake made possible by a poor initial placement on the goats' side. However, on their third turn, the tigers miss a capture opportunity, allowing the goats to strengthen their position on the fourth turn.



1st turn 2nd turn

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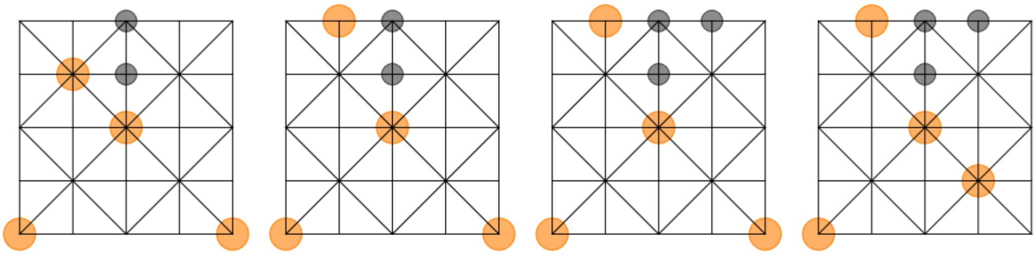

3rd turn 4th turn

Figure 5. Possible opening sequence up to the fourth turn.
The larger orange circles represent tigers, whereas the smaller grey ones represent goats.

During the second phase, which starts once the 20 goats have been placed into the board, goats can start moving, one per turn, to a free adjacent intersection along a line. They cannot capture tigers. Tigers' movement and capture rules are the same in both phases.

4.2.3. Regarding strategy and tactics

Bagh chal is not as widely popular and studied as chess is, this limiting information about possible winning or facilitating strategies. "The placement phase involves a search whose game-tree complexity is estimated to be of the order 10^{41}", according to Lim and Nievergelt (2004, p. 131). Ignoring symmetric variants, the number of possible positions during the placement phase is 6,633,059,000, while during the movement phase, it is 88,260,972 (Lim & Nievergelt, 2004). Size and structure of the state space significantly delayed the game's computational analysis, even though it was finally determined that when played optimally on both sides bagh chal ends in a draw (Lim & Nievergelt, 2009).

Figure 6 shows the five possible opening moves for the goats. Any other choice is analogous to one of these five, due to the symmetry of the game board. Options (a) and (b) in the figure expose the goat, offering an immediate capture. Option (d) allows the tigers to force a capture in their second turn, as sequence on **Figure 5** shows. Option (e) gives optimally playing tigers the possibility to force an early capture, which should occur at most in their fifth turn, since in their fourth turn they can make a move that is called "scissors" in chess, a double-threat so that the defender can save only one of the exposed goats with the other one being inevitably captured. Option (c) is the only one which allows goats to start a solid cantonment and avoid an early capture. Hence, the goats' first move is practically mandatory among those available if they are not willing to make an early sacrifice.

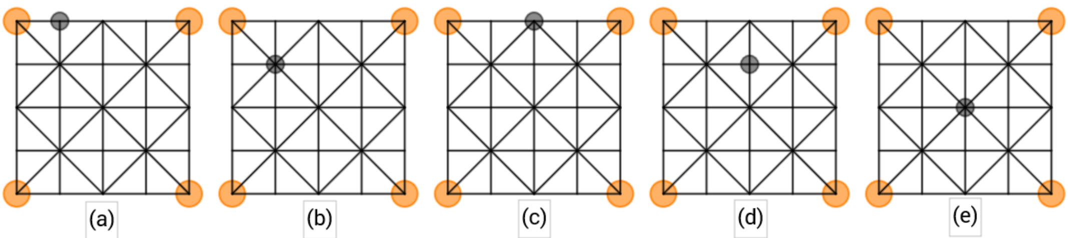

Figure 6. Possible opening moves for the goats

A facilitating strategy for the goats during the placement phase is to occupy the board sides and corners. During the movement phase, there is one simple principle: the goats must try to advance in unison in order to trap the tigers. They can manage to do so if they get to introduce free points into the herd space, rendering them inaccessible to the tigers via jumps; in this way, they effectively control available space and can hold it so that it is not returned into dispute, considerably reducing the tigers' mobility.

Optimally playing tigers can force the capture of at least two goats during the placement phase. Nevertheless, if they do not take this advantage and that phase ends with only one free point, the game becomes complicated for them due to the mobility reduction. In that situation the goat herd can frequently maintain a closed formation long enough to corral the tigers. During the movement phase the tigers have little choice but to wait for the goats' mistakes (sub-optimal decisions), thus limiting tiger choices to tactical aspects. For the tigers, two fundamental goals at any moment are looking for scissor-like moves and keeping as scattered on the board as possible, thus threatening more space for plausible captures and trying to avoid being blocked all at once.

4.3. The game-socifact. Sociocultural aspects of the game

The game's name bagh chal (□□□ □□□ *bāgh cāl*, in Nepali language, □□□ □□□□ *dhun kasa*, in Newar or Nepal Bhasa) can be translated as "the tiger moves" or "the tiger's movement". The tiger is commonly considered king of the animals in Asia and therefore has a leading role in several games from East and Southeast Asia which represent the tiger's hunt of different prey.

Bagh chal is Nepal national game and said to be "ideal to play when the summer mornings' sun is too strong". Nepali tradition says the game was created by Mandodari (**Figure 7**), daughter of Mayasura, King of the *Asuras*, and Hema, *apsara* water nymph. Mandodari ("soft-bellied") is Queen consort of Ravana, King of Lanka, according to the Hindu epic Ramayana, and belongs to the *Panchakanya*, a group of five maidens the recital of whose names is believed to dispel sin.

4.4. STEM aspects of interest

With this Playful Projects, educators can work on the following STEM aspects with students-participants:

- Pieces involved: characterization, identification, count; representation of the abstraction.
- Board abstract geometry: 1. Descriptive aspects: characterization, constituent elements, symmetry. 2. Constructive aspects: freehand, compass and straightedge, GeoGebra, other tools.
- Game tree: subset graph of the extensive-form game, representing the game development from the start up to a given time.
- Next-move tree: subset graph of the extensive-form game, representing mental forecast of the game development from a given time, showing several possible sequences of future moves.
- Abstract codification systems: to annotate game development representing moves in a coded record of the game-tree nodes actually traversed.
- Argumentation.
- Deductive reasoning.

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- Spatial thinking: 1. Orientation: localization and description of moves in a plane, cardinal points, technological tools (compass or GPS). 2. Representation: Cartesian axes and coordinates, floor plan, relation to maps and scales.
- Predation: biological interaction in ecosystems. Predators and prey. Food chain and trophic levels.
- Natural environment: impact on cultural idiosyncrasies. Geographical, climatological, and natural characterization of the origin.
- Predator-prey mathematical model: Lotka-Volterra's equations.
- Technological aspects: 1. Material selection: usage of recycled materials; reason and convenience; practical, economic and ecologic considerations. 2. Construction of board and pieces: tool selection, size choice, construction execution.
- Artistic aspects: design, craft, and decoration of board and pieces.

Figure 7. Hanuman obtaining Mandodari's weapon which will lead to Ravana's death (Source: unknown author, https://en.wikipedia.org/wiki/Mandodari#/media/File:Hanuman_obtaining_Mandodari%27s_weapon.jpg)

4.5. Activities and suggested itineraries

This Playful Project includes 11 activities specifically designed to work on the STEM aspects indicated above through tasks pursued around bagh chal. Each activity is accompanied by several questions that the educator can ask to stimulate the enquiry process. Many of these questions can precede the practical work, so that participants can consider an *a priori* hypothesis to be validated or refuted through practice and then can draw conclusions based on argumentation. Due to space constraints, here we present only four of these activities, omitting corresponding questions. The rest will be addressed in a different publication.

The sequence of activities 1-5-7 constitutes a shortened version of the Playful Project, recommended for time-constrained courses, workshops or events. It covers many of the STEM aspects of interest, fostering scientific and mathematical thinking through a playful, motivating, and stimulating educational action.

4.5.1. Activity 1: "Getting to know bagh chal"

A traditional version of the game of bagh chal is presented, and participants are asked to describe the board and the pieces, emphasising quantitative, morphological, and geometric considerations, and explaining peculiarities found.

4.5.2. Activity 5: "Learning bagh chal"

After the rules of the game are explained, participants are grouped in couples and invited to begin playing and exploring the game in search of strategies. All participants are requested to play the same number of games playing the tiger side as playing the goat side. After a pre-established number of games, participant couples are gathered to debate their findings in a discussion group. All participants are encouraged to take part in communicating their impressions about the game, the difficulties encountered, their ideas about strategies or tactical decisions, their preference of tigers or goats, etc., using argumentation in their responses.

4.5.3. Activity 7: "Role-playing bagh chal"

A total of 24 volunteers are needed, 20 of them disguised in some way as goats and four as tigers. Each participant to take part in the role playing must contribute a sweet, for a pot of 24 sweets. Also, a giant bagh chal board is needed (it can be drawn on the school playground or the street using chalk; we recommend approximately 1 metre or 1 yard between adjacent lines).

After the board and participants are arranged, the goal is to play a bagh chal game with the participants as pieces. Each side needs to agree on how their moves will be decided. At the end of the game, the winning side will be rewarded the pot of 24 sweets, to divide equitably among its members. All decisions must be justified.

It is very useful to compare the way of playing the game on a board (floor-plan view or bird's eye view) to the way of playing with participants as pieces (perspective view or from within).

4.5.4. Activity 8: "Contextualising bagh chal"

The sociocultural, geographical, and natural contextualisation of the game is provided. The concepts of ecosystem and biological interaction are approached, emphasising predation as an interaction type. The conversation can include the concepts of food chain and trophic levels as well as the impact of natural environment in cultural features. It is helpful to discuss whether the relation presented in the game is the same as what occurs in the natural environment, and whether it resembles any other known interaction between species.

5. Conclusions

This work introduces a methodology based on Playful Projects as an adaptation of Ethnomathematical Microprojects. These Playful Projects are open interdisciplinary teaching modules, constructed around a world board game interpreted as a sociocultural and ethnomathematical object of interest. They are specifically designed to contribute to scientific and mathematical education in non-formal contexts. Playful Projects, implemented via series of one-hour sessions, encompass sequences of learning, communication, and reflective action activities, which are meant to motivate participants and foster scientific and mathematical thinking as well as enquiry.

The Playful Project entitled "Bagh Chal, a Tigers-and-Goats Game", based on Nepali traditional game bagh chal, is presented. This game represents a confrontation between two asymmetrical forces in a hunt scenario. The Playful Project has been designed to work on several relevant aspects from a STEM educational perspective, such as spatial thinking and orientation, geometric modelling, strategy, deductive reasoning, representation, coding, analogy, scientific speech, biological interactions.

We propose this as a pertinent and enriching approach to scientific and mathematical education through world-games-based proposals, firstly, because play is a teaching resource proven to activate emotional and cognitive factors, thus fostering the development of multiple skills; and secondly, because these games are samples of cultural scientific and mathematical thinking (Bishop, 1998; Gerdes, 1988) that can encourage intercultural and interdisciplinary education, a fundamental need in today's evermore globalized world.

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References

Acevedo, J. A. (2004). Reflexiones sobre las finalidades de la enseñanza de las ciencias: educación científica para la ciudadanía. *Revista Eureka sobre Enseñanza y Divulgación de las Ciencias, 1*(1), 3-16.
Ballesteros, S. (2005). *Juegos de mesa del mundo*. Madrid: CCS.
Barab, S. A., & Landa, A. (1997). Designing Effective Interdisciplinary Anchors. *Educational Leadership, 54*(6), 52-55.
Bergen, D. (2009). Play as the Learning Medium for Future Scientists, Mathematicians and Engineers. *American Journal of Play, 1*(4), 413-428.
Bishop, A. J. (1998). El papel de los juegos en educación matemática. *Uno. Revista de Didáctica de las Matemáticas, 18*, 9-19.
Eccles, J. S., Barber, B. L., Stone, M., & Hunt, J. (2003). Extracurricular activities and adolescent development. *Journal of Social Issues, 59*(4), 865-889.
Eccles, J. S., & Templeton, J. (2002). Extracurricular and other after-school activities for youth. *Review of Research in Education*, 113-180.
Esteban, S. (2003). La perspectiva histórica de las relaciones Ciencia-Tecnología-Sociedad y su papel en la enseñanza de las ciencias. *Revista Electrónica de Enseñanza de las Ciencias, 2*(3), 399-415.
Ferguson, R. (1995). *Chess in Education Research Summary. A Review of Key Chess Research Studies*. Paper presented at the Borough of Manhattan Community College "Chess in Education: A Wise Move" Conference, New York.
Fernández-Oliveras, A., & Oliveras, M. L. (2014a). Playing for science and mathematics education: an experience for pre-service kindergarten teacher training. In M. F. M. Costa, P. Pombo, B. V. Dorrío

(Eds.), *Hands-on Science. Science Education with and for Society* (180 -183). Braga: Hands-on Science Network. Retrieved from http://www.hsci.info/Book_HSCI_2014_ lowresA4.pdf.

Fernández-Oliveras, A., & Oliveras, M. L. (2014b). Pre-service kindergarten teachers' conceptions of play, science, mathematics, and education. *Procedia - Social and Behavioral Sciences*, 152, 856-861. DOI: 10.1016/j.sbspro.2014.09.334.

Fernández-Oliveras, A., & Oliveras, M. L. (2015). Conceptions of science, mathematics, and education of prospective kindergarten teachers in a play-based training. *International Journal on Advances in Education Research, 2*(1), 37-48. Retrieved from http://edure.org/EduReJournalVol2N1/ EduRe_V2_I1_P3.pdf.

Gerdes, P. (1988). On culture, geometrical thinking and mathematics education. *Educational Studies in Mathematics, 19*(2), 137-162.

Gutiérrez-Perera, C. S. (2014). *Programación didáctica de la asignatura de 4º de ESO Trabajo Monográfico de Investigación: "Juegos de mesa del mundo y etnomatemáticas"*. Unpublished master's thesis, Universitat Jaume I, Castelló, Spain. Retrieved from http://repositori.uji.es/xmlui/handle/10234/108258.

Gutiérrez-Perera, C. S., Fernández-Oliveras, A., & Oliveras, M. L. (2015). Analizando y seleccionando juegos del mundo para la educación científica y matemática. *ReiDoCrea, Revista electrónica de investigación y Docencia Creativa, monográfico Enseñanza y Aprendizaje de las Ciencias Experimentales y las Matemáticas*, 22-27. Retrieved from http://hdl.handle.net/10481/37111.

Huxley, J. S. (1955). Evolution, Cultural and Biological. *Yearbook of Anthropology* (pp. 2-25). Chicago: University of Chicago.

Leyton-Brown, K., & Shoham, Y. (2008). *Essentials of Game Theory: A Concise Multidisciplinary Introduction*. San Rafael, California: Morgan & Claypool.

Lim, Y. J., & Nievergelt, J. (2004). Computing Tigers and Goats, *ICGA Journal, 27*(3), 31-141.

Lim, Y. J., & Nievergelt, J. (2009). Tigers and Goats is a draw, *Games of No Chance 3*, 163-176. MSRI. Cambridge: Cambridge University Press. DOI: 10.1017/CBO9780511807251.008.

Mahoney, J. L. (2000). School extracurricular activity participation as a moderator in the development of antisocial patterns. *Child development, 71*(2), 502-516.

Melo, M. P., & Hernández, R. (2014). El juego y sus posibilidades en la enseñanza de las ciencias naturales. *Innovación Educativa, 14*(66), 41-63.

Newcombe, N. S. (2010). Picture This. Increasing Math and Science Learning by Improving Spatial Thinking. *American Educator*, summer 2010, 29-35+43.

Oliveras, M. L. (2005). Microproyectos para la educación intercultural en Europa. *Uno: Revista de Didáctica de las Matemáticas, 11* (38), 70-81.

Oliveras, M. L. (2008) The IDMAMIM project is "Innovation in Didactics for Mathematics in Multicultural contexts, with Immigrant and Minority pupils". ICME 11. Monterrey, México. Topic Study Group 33: *Mathematics education in a multilingual and multicultural environment*.

Sanmartí, N., & Marchán, I. (2015). La educación científica del siglo XXI: retos y propuestas. *Investigación y Ciencia*, (469), 30-38.

Shoham, Y., & Leyton-Brown, K. (2010). *Multiagent Systems: Algorithmic, Game-Theoretic, and Logical Foundations* [online]. Cambridge: Cambridge University Press (2008). Retrieved from http://www.masfoundations.org/download.html [accessed, 8 march 2016].

Wan, X., Nakatani, H., Ueno, K., Asamizuya, T., Cheng, K., & Tanaka, K. (2011). The Neural Basis of Intuitive Best Next-Move Generation in Board Game Experts. *Science*, 331, 341-346.

Williford, H. (1992). Games for Developing Mathematical Strategy. *Mathematics Teacher, 85*(2), 96-98.