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Integrating knowledge in higher education: using body experiences to enable transdisciplinarity based on Dynamic Systems Theory general concepts

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Rafa Nadal and Carlos Alcaraz of Spain in action against Tallon Griekspoor and Wesley Koolhof of Netherlands during their men's doubles second round tennis match at the Paris Olympic Games on July 30, 2024. (Photo by EFE/EPA/ Ritchie B. Tongo)

Abstract

This study aimed to evaluate the effectiveness of learning Dynamic Systems Theory (DST) general concepts for enhancing integrative knowledge and transdisciplinarity among higher education students of sports sciences. Two class groups of first-cycle students were assigned to the experimental (EG, n = 147) and control (CG, n = 140) groups, respectively. The EG followed a specific intervention consisting of learning DST general concepts and experiencing their transdisciplinarity, while the CG followed the regular lessons. Integration and transfer of knowledge were evaluated through questionnaires and oral presentations. Post intervention, the EG group significantly improved their integrative and transdisciplinary knowledge, while the CG showed no change. Learning DST concepts using body experiences and applying them to sports science phenomena effectively fostered integrative knowledge among higher education students.

Keywords: complex systems, education innovation, embodied learning, sports sciences, transfer of knowledge, university.

Introduction

In the traditional educational curricula, subjects are often taught in isolation and disconnected from each other (Hristovski et al., 2020). By failing to recognise the interconnectedness of knowledge across disciplines, learners miss opportunities to apply what they have learned to real-world problems (Adams, 2015; Bautista et al., 2018). Research shows that students who were taught in a fragmented manner had limited transferability of knowledge to new contexts (Ball, 2000). More concretely, standard instructional practices in undergraduate teaching, such as traditional lectures, laboratory, or recitation courses, are ineffective at helping students to master and retain important concepts of the disciplines over the long term (Wood & Gentile, 2003). Moreover, these practices do not adequately develop the integration of knowledge and collaborative problem-solving competencies needed to face the problems of the modern world.

In contrast, students who received a more integrated education (e.g., problem-based learning or inquiry learning) demonstrated higher levels of understanding of the topic and could better apply their knowledge effectively (Hmelo-Silver et al., 2007). However, the use of subject-specific vocabulary in different disciplines makes it challenging to implement transdisciplinary approaches (Hristovski, 2013; Hristovski et al., 2020). A transdisciplinary approach to education focuses on solving problems that require the interconnection of knowledge across disciplines, blurring the boundaries to generate new knowledge (McGregor, 2015). For example, in sports sciences, experts such as physiologists, psychologists, sociologists, biomechanics, sports coaches, and data analysts may face communication barriers due to differences in scientific terminology and approaches. In such cases, a common scientific language could facilitate their understanding, which is crucial for the progress of science and society.

To understand and unify approaches in science, general concepts and principles that can explain different phenomena (e.g., fatigue, injuries, performance, etc.) are needed. The Dynamic Systems Theory (DST) offers a comprehensive set of interconnected general concepts and principles that have been empirically identified (Hristovski, 2013; Hristovski et al., 2014, 2019). Using DST concepts can help to understand phenomena and dynamic processes from a broad spectrum of scientific disciplines (i.e., from elementary particles and fields to sociology) and integrate knowledge. This includes sports sciences (Balagué et al., 2017; Vázquez, 2017; Hristovski, 2013) with its multilevelness and multidimensionality. In this sense, DST has the potential to provide a basic understanding of diverse phenomena from various academic disciplines.

When researching the effectiveness of transdisciplinary educational interventions, short questionnaires completed by students are commonly used (Takeuchi et al., 2020; Lage-Gómez & Ros, 2021). In particular, questionnaires tailored to the content appear to be the most suitable since assessing objectively knowledge transfer is challenging. In this case, the utilization of constructed-response items, also known as open-ended questions, are assessment items that require generating a response rather than selecting it from a set of options. These questions offer students valuable opportunities to justify their answers and prove to be a beneficial learning approach (McCarthy, 2005). Open-ended questions are commonly used in various forms of assessments, such as educational exams, surveys and interviews. Liu et al. (2011) proposed applicable criteria for particularly assessing knowledge integration through short questionnaires.

On the other hand, learning by experiencing first can be more effective in consolidating theory for students. For example, body movement experiences have been used to study concepts in mathematics, physics, biology, music, or culture (e.g., interdisciplinary physical education [Cone et al., 2009]) or transdisciplinary concepts in primary and secondary education (Almarcha et al., 2022; Almarcha et al., 2023). These experiences have shown better outcomes when working in groups because of the extent of collaborative peer learning (Magin, 1982). One example of practical experience to explain theoretical subjects in university settings is the study conducted by Hernández (2019), where students learned the kinematics of bicycle physics by riding a bicycle. Another university experiment showed that a centre for "learning how to learn", based on learning through teaching, reduced attrition and improved tuiton and student skills (Wankowski, 2007).

The Synthetic Understanding through Movement Analogies (SUMA) educational framework arises from the need to help acquiring general DST concepts and integrate disciplines through embodied learning (Hristovski et al., 2020). That is, the understanding of concepts and principles through somatosensory, perceptual and re-experiencing actions without segregating action and thinking processes as two unrelated realms (Niedenthal, 2007; Stolz, 2015; Skulmowski & Rey, 2018). Based on this framework, we hypothesised that learning through embodied experiences will positively affect acquiring general DST concepts and their transfer role among phenomena in university settings.

This research aimed to evaluate the educational potential of experiencing some DST concepts (see Table 1) for enhancing integration and transfer of knowledge among higher education students of sports sciences. This

Table 1
Dynamic Systems Theory (DST) general concepts[1] used during the sessions followed by the experimental group (all the proposed concepts are retrieved or derived from SUMA educational framework [Hristovski et al., 2020]. The derived concepts are marked by an asterisk).

DST Concepts	Definition
Self-organization	Spontaneous process where some form of overall order arises from local or global interactions between parts of an initially disordered system.
Synergies*	Spontaneous formation of structural and functional couplings among components, which reciprocally compensate each other with respect to the context, to achieve task goals.
Emergence	Radical novelty in the higher-level behavior of systems resulting from interactions in the lower-level components within those systems.
Nestedness*	Larger to smaller emergent levels of organization. Smaller modules, each of them providing a certain function, are used within larger modules that perform more complex functions.
Dynamic system	System changing over time.
Stability	Resilience to perturbations. The necessary and sufficient condition for the existence of any system's behavior/structure.
Instability	The behavior/structure of a system which tends to vanish and switch to a stable state.
Phase transition	The spontaneous qualitative change of the system as a result of the instability of the previous state.
Attractor	Behavioral or structural states toward which, under some specific context, the system converges over time.
Repeller	Unstable state of system's behavior.
Constraint/context	Boundary conditions, limitations that apply restrictions to the degrees of freedom of a system.

[1] Synergies and nestedness are not truly DST concepts but are derivable from them and have a wide explanatory scope within the bio-psycho-social sciences.

study aimed to evaluate the effectiveness of learning DST concepts (see Table 1) for enhancing integrative knowledge and transdisciplinarity among higher education students of sports sciences.

Methods

Participants

Two hundred eighty-seven first-cycle degree program students of sports sciences aged between 18 and 36 years old (M = 20.07 ± 3.85) from the same faculty participated in the study. Two class groups with no significant differences in average sex, age, and educational interest were selected for the study. A total number of 147 students (37 women and 110 men) were assigned to the experimental group (EG) and 140 (34 women and 106 men) to the control group (CG). The female representation reflected the gender distribution of the whole degree program. Students were not previously introduced to or familiar with DST concepts. Once the intervention was explained, the students gave informed consent to participate. The institution and the local research ethics committee approved the research (072015CEICEGC). The data was coded anonymously to ensure confidentiality, adhere to university ethics, and comply with relevant guidelines and the principles of the Declaration of Helsinki.

Procedure

The study was conducted in the university faculty and integrated into the teaching general program. The intervention lasted 12 weeks and had a frequency of two theoretical lessons and one practical lesson per week of 90 minutes each. It was led by an experienced teacher who applied DST concepts and two researchers working in the same field.

During class time, on the first day and at the end of the intervention program, all participants filled out a demographic form and the Integrative Knowledge Questionnaire (see Evaluation section). Then, the EG followed the intervention, while the CG did not participate. Both groups continued with the university-programed lessons.

Intervention program

The intervention program consisted of two phases: a) preparatory and b) team's work oral participation in a symposium.

a) Preparatory.

The preparatory phase consisted of three learning phases (adapted from Hristovski et al., 2014, and Kolb, 1984):

1. Embodied learning: Experiencing the general DST concepts (see Table 1) through physical activities (11 sessions). For example, the stability, instability, and phase transition concepts were experienced through the dynamics of task-related and task-unrelated thoughts during an incremental cycling task, or the intra- and interpersonal

synergies of body components were experienced through a cooperative dyadic task on a slackline.

2. Far-transfer transdisciplinary: During each practical session, the teacher guided the students to answer specific questions to relate the body experiences with the general DST concepts (11 sessions). For instance, when the students recorded their thoughts during an incremental cycling task, they were asked to explain how they related the changes in their thought patterns with stability, instability, and phase transition, among others.

3. Theoretical lessons on general DST concepts (11 sessions). The theoretical lessons consisted of explaining each DST concept by providing examples of different phenomena.

b) Team's work participation in a symposium.

With the purpose of applying and experimenting the transdisciplinarity of general DST concepts, students prepared team works to be presented in a symposium. Student groups with common theoretical and practical interests (4-5 members) selected a topic or phenomenon related to health, sports performance, or education to be explained using DST general concepts. Moodle platform chats were used to avoid topic overlaps when selecting topics. Once the topics were assigned to the teams, students worked collaboratively to submit an abstract (including authors, title and references) to participate in the symposium. When the abstract was accepted by the teachers, they could present their works orally. A period of two weeks was left for correcting and resubmitting abstracts. During the process, the teachers offered additional support, providing regular tutoring and follow-up discussions to ensure that every team could satisfy the rubric of the oral presentations (see Table 2).

The symposium program was scheduled for six sessions covering the following general topics: nutrition, health, injuries, performance, team sports, and education. Each presentation lasted 12 min plus 10 min of questions. After each presentation, all students and teachers scored the oral presentations and discussions following a rubric (Hafner & Hafner, 2003) (see Table 2), and added a comment to justify the score.

Evaluation

Knowledge Integration Questionnaire

Students had to answer the following questions:

1. Do you think it is scientifically interesting to explain any natural phenomenon using the same general DST concepts?

2. (2.1) Can you identify common DST principles in biological, psychological, and sociological processes? (2.2) Which ones?

3. Can you use the general DST concepts to explain a phenomenon such as a social revolution? Please justify it.

4. And for explaining an organic injury? Please justify it.

The content validity of the questionnaire was established by two researchers with 30 years of experience in using DST concepts and evaluated by a researcher from the SUMA project (Hristovski et al., 2020). The assessed inter-item reliability of the questionnaire, measured through Cronbach's alpha, was α = .92.

Table 2
Rubric embedded in the form to evaluate the team presentations.

	Punctuation				
Items	Excellent (4)	Good (3)	Adequate (2)	Deficient (1)	Percentage of qualification
Integration of concepts	Good domain of the concepts and respond coherently to the questions.	Understand the explained phenomenon but have difficulties to link some concepts.	Need some rectifications about the usage of the concepts.	Have no understanding of the concepts.	40 %
Collaborative work	The presentation shows planification and collaborative work. All the members participate actively.	The presentation shows planification, but some members present deviations from the group's framework.	The presentation shows some planification, but with different levels of participation among the members.	There is no collaboration or even no participation by the members.	40 %
Originality and quality	Original topic. Adequate and attractive visual support.	Original topic. Adequate but few attractive visual support.	Non-original topic. Adequate visual support.	Non-original topic. Inadequate visual support.	20 %

Evaluation of the team presentations

All students were required to assess the work of the other teams using an online form linked to a rubric. The rubric had three items —“integration of concepts”, “collaborative work”, and “originality and quality”— each of which was evaluated on a 4-point scale ranging from 1 (deficient) to 4 (excellent). Table 2 displays the rubric items and the percentage of grades used to evaluate the team presentations.

Students’ satisfaction survey

Post intervention, a students’ satisfaction survey was administered to collect the acquired competencies in integrating and transferring knowledge and the collaborative learning benefits.

Data Analysis

Knowledge Integration Questionnaire

Descriptive statistics were used to interpret the quantitative data. The percentages of Yes/No answers for questions 1 and 2.1 and the correct/incorrect answers in 2.2, 3 and 4 in pre- and post-intervention were calculated for the EG and CG. A Chi-square test of independence was performed to compare the differences between the groups, while McNemar’s test was used to compare the results for each question within groups.

Evaluation of the team presentations

The mean and standard deviation (SD) of the students’ and teachers’ marks (out of 10) associated with the first item of the rubric (use of general DST concepts to explain the phenomenon under study) was calculated to evaluate their integrative and transdisciplinary knowledge. The mean and SD of the students’ and teachers’ marks (out of 10) associated with the other three items were respectively calculated. The mean final marks provided by students and the consensual marks of the teachers for each presentation were compared through Spearman’s rank correlation. For all statistical analyses, SPSS 23.0 (SPSS, Chicago, IL, USA) was used and the significance alpha level was set at $p < .01$.

Students’ satisfaction survey

The percentage of responses to every question of the students’ satisfaction survey was calculated.

Results

Knowledge Integration Questionnaire

Table 3 displays the percentage of responses for both groups. Before the intervention, as neither group had knowledge of the general DST concepts, almost no student could answer questions 2.2, 3, and 4. However, both groups shared similar responses in questions Q.1 ($\chi^2 = 0.119$, $p = .827$), Q.2.1 ($\chi^2 = 0.733$, $p = .858$) and Q.4 ($\chi^2 = 0.289$, $p = .966$). Contrarily, post intervention the differences between groups were significant in every question Q.1 ($\chi^2 = 81.428$, $p < .001$), Q.2.1 ($\chi^2 = 152.821$, $p < .001$), Q.2.2 ($\chi^2 = 186.998$, $p < .001$), Q.3 ($\chi^2 = 163.596$, $p < .001$), and Q.4 ($\chi^2 = 181.583$, $p < .001$).

When comparing differences within groups, the CG did not differ between pre and post Q.1 ($\chi^2 = 3.00$, $p = .083$), Q.2.1 ($\chi^2 = 2.00$, $p = .157$), Q.2.2, Q.3 and Q.4 ($\chi^2 = 1.00$, $p = .317$). In contrast, the EG presented significant differences in Q.1 ($\chi^2 = 77.00$, $p < .001$), Q.2.1 ($\chi^2 = 111.00$, $p < .001$), Q.2.2 ($\chi^2 = 118.00$, $p < .001$), Q.3 ($\chi^2 = 109.00$, $p < .001$), and Q.4 ($\chi^2 = 116.00$, $p < .001$).

Table 3
Percentages of responses to the Knowledge Integration Questionnaire.

Questions	CG (*n* = 140)		EG (*n* = 147)	
	Pre	Post	Pre	Post
	Yes	Yes	Yes	Yes/correct
1. Do you think it is scientifically interesting to explain any natural phenomenon with the same concepts?	44 (31 %)	47 (34 %)	49 (33 %)	126 (86 %)* ǂ
2.1 Can you identify common principles of CAS and general concepts of DST in biological, psychological and sociological processes?	23 (16 %)	25 (18 %)	22 (15 %)	133 (90 %)* ǂ
2.2 Which ones?	1 (0.71 %)	1 (0.71 %)	2 (1.36 %)	118 (80 %) ǂ
3. Can you use the general concepts (attractors, instability, variability, synergies, etc.) to explain a phenomenon such as a social revolution?	1 (0.71 %)	1 (0.71 %)	2 (1.36 %)	109 (74 %)* ǂ
4. And for explaining an organic injury?	1 (0.71 %)	1 (0.71 %)	2 (1.36 %)	116 (79 %)* ǂ

Notes: *Significant differences when compared with the post-CG data. ǂ Significant differences when compared with the pre-EG data. CG = control group, EG = experimental group; CAS = complex adaptive systems, DST = dynamic systems theory. 2.2 question was a descriptive response to confirm 2.1 question.

Table 4
Percentages of responses to the students' satisfaction survey.

Students' responses (n = 114)					
Survey questions	Not at all	A little	Neutral	Very	Very much
1. Are you satisfied with what you learned in the course?	10 (8.78 %)	5 (4.38 %)	11 (9.65 %)	60 (52.63 %)	28 (24.56 %)
2. Would you like to keep learning these concepts as well as their application at different levels?	6 (5.26 %)	7 (6.4 %)	18 (15.79 %)	55 (48.25 %)	28 (24.56 %)
3. Do you think that collaborative learning (symposium, co-evaluation, etc.) has helped you to go deeper into the course's knowledge?	8 (7.02 %)	5 (4.38 %)	16 (14.04 %)	35 (30.70 %)	50 (43.86 %)

Evaluation of the team presentations

A total number of 54 works with different topics of interest were evaluated. Integration of knowledge (item 1) was assessed with a mark of 8.43 ± 0.88 (Min = 5.35, Max = 9.70), the team's collaborative work (item 2) with a mark of 8.91 ± 0.45 (Min = 7.55, Max = 9.55), and the originality of the work (item 3) with a mark of 8.52 ± 0.55 (Min = 6.72, Max = 9.47). Teachers' and students' final marks (7.36 ± 1.65 and 8.18 ± 0.96, respectively) showed a positive correlation ($rho = 0.8$, $p < .01$) and confirmed the objectivity of the judges.

Students' satisfaction survey

The survey was responded by 114 students, of which 77.19 % were satisfied with the intervention, 72.81 % expressed the will to continue learning to apply DST concepts to different psychobiological and sociological phenomena, and 74.56 % expressed that collaborative learning helped them to deepen their knowledge (see Table 4 for further information).

Discussion

The intervention results revealed that by experiencing the general DST concepts, students could integrate and transfer knowledge effectively, leading to an increased interest in explaining natural phenomena using the same concepts. Their grades supported this outcome and demonstrated their ability to apply the general DST concepts to the selected topics of interest. The positive correlation between the marks awarded by the students and teachers confirmed the objectivity of the assessment. Additionally, the students agreed that the team's collaborative dynamics was an efficient strategy for achieving the purpose of the intervention.

The intervention significantly impacted the EG's integration and transfer of knowledge abilities. Meanwhile, the CG showed no improvement, which can be attributed to their lack of exposure to learning DST concepts. In turn, the increase of integrative and transfer knowledge abilities of EG can be attributed to several aspects of the intervention program. First, the sessions were designed to experience the DST concepts through embodied learning, which have gained some popularity in education due to their effectiveness in enhancing cognitive abilities and improving knowledge retention (Clary & Wandersee, 2007; Schwartz-Bloom et al., 2011; Spintzyk et al., 2016). When general concepts were embodied, explained and identified in different phenomena, the capacity to transfer knowledge among disciplines improved. It is worth mentioning that transdisciplinarity was based on DST concepts but not transferred by themselves. DST concepts connect two or more different phenomena and hence transfer the knowledge from the source phenomenon to the target phenomenon. Transdisciplinarity is realised when students connect different phenomena in the later parts of the learning. Hence, the reflective observation of these experiences involved the comprehension, abstract conceptualisation, transference, and retention of the general DST concepts. These results are consistent with those reported by Almarcha et al. (2022, 2023) in primary and secondary school.

The symposium's organization created an ideal environment for students to understand different phenomena, transfer the knowledge to topics that are of personal interest, and thus acquire transdisciplinary competencies. According to Cabrera et al. (2017), allowing students to work on a meaningful topic contributes to improving their motivation. Prince (2004) agreed that optimal learning comes from active engagement with the material being taught.

Also, a collaborative, supportive and pleasant classroom atmosphere contributed to the emergence of students' questions and arguments, which can often be more valuable than the lessons themselves. Classroom interactions between teachers and students seem more effective than traditional teaching methods and active learning situations in promoting participatory engagement (Bartlett & Ferber, 1998; Smith & Cardaciotto, 2011; Yoder & Hochevar, 2005).

The Knowledge Integration Questionnaire and satisfaction survey results showed that students believed they had improved their knowledge integration and transfer skills, became more interested in science, had a positive experience with collaborative learning, and that working on a relevant topic had boosted their motivation and creativity. The satisfaction survey data showed that the discussions and tutoring during the entire learning process helped students consolidate their learning. As Ko and Mezuk (2021) found, the teachers' tutorial guidance and internal group discussions seemed key to the intervention's success.

Despite the strengths of this study, some limitations must be considered. First, the long-term effects of the intervention, such as the future professional implications of learning these concepts at the university, have yet to be evaluated. Also, as suggested by Hristovski et al. (2020), according to the SUMA framework, most educational interventions ignore the importance of embodied experiences in learning. Future interventions may enhance the learning process of general DST concepts using an embodied learning approach, as highlighted in this and previous studies (Almarcha et al., 2022, 2023; Hristovski et al., 2014).

Additionally, we did not conduct a gender analysis of the results due to the small number of female participants compared to male participants. We suggest incorporating interviews throughout the academic program to better understand how students develop knowledge transfer competencies during the intervention.

Future research should continue to investigate the potential of general DST concepts not only at any education level, but also in professional fields like interdisciplinary sports teams.

Conclusion

The intervention highlighted that learning DST concepts using body experiences and applying them to sports science phenomena effectively fostered integrative knowledge among higher education students. This transdisciplinary knowledge can potentially provide a shared understanding among different disciplines either for sports sciences (e.g., physiology, biomechanics, psychology, etc.) or other areas of knowledge.

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