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Analysis of Human Anatomy Education: The Effects of a Gamified Creativity-Based Teaching Method on Students' from Basic Psychological Needs Frustration

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Abstract
According to self-determination theory, frustration of basic psychological needs (autonomy, competence, and relatedness) leads to ill-being and negatively affects the learning process. The present study aimed to analyze the effects of a gamified creativity-based teaching method of human anatomy on basic psychological needs frustration compared with a conventional teaching method. A quasi-experimental design was employed, comparing two anatomy educational treatments (experimental and control) over a 7-week period. A total of 116 first-year students from two Spanish public universities was participated. The Basic Psychological Needs Frustration Scale was utilized, and pre- and post-treatment measurements were collected. Statistical analyses included independent samples *t*-tests, one-way ANCOVAs, and a factorial repeated measures ANCOVA 2 × 2 (time × treatment), comparing two groups based on time (baseline vs. follow-up) and treatment (control vs. experimental). The analysis revealed that the gamified creativity-based program achieved lower frustration of basic psychological needs compared to the control treatment ($t\,(108) = 3.74$, $p < .001$, $d = 0.68$) and a treatment effect was observed ($F\,(1) = 9.06$, $p = .003$, $\eta^2_p = .083$). Autonomy and competence frustration significantly increased in the control group, while apparently remained consistent over time in the treatment group. Baseline and follow-up significant differences were found for relatedness ($t\,(114) = 1.12$, $p = .03$, $d = 0.4$; $t\,(110) = 2.88$, $p = .005$, $d = 0.53$, respectively), as well as a treatment effect ($F\,(1) = 7.28$, $p = .008$, $\eta^2_p = .069$). These findings provide support for the idea that students' basic psychological needs are lower frustrated with the implementation of a gamified creativity-based teaching method in anatomy education.

Keywords Human anatomy teaching · Anatomy learning · Self-determination theory · Psychological frustration · Natural experiment

Introduction

According to self-determination theory (Ryan & Deci, 2017), frustration of basic psychological needs can adversely affect well-being and hinder the learning process, especially in teaching human anatomy. Human anatomy plays a pivotal role and is fundamental to health sciences programs at the university level. This subject can present significant challenges to first-year college students, primarily attributed to the abstract nature of its concepts, the intricate complexity of anatomical structures, the requirement to comprehend a substantial amount of information, and time constraints (Cheung et al., 2021). Consequently, students might experience an initial sense of discouragement, leading them to resort to rote memorization to cope with the overwhelming intrinsic load, which can subsequently curtail their learning motivation (Cheung et al., 2021).

Furthermore, emotions such as boredom (Camacho-Morles et al., 2021; Loderer et al., 2020; Tze et al., 2016), which may arise in specific instructional contexts, exert a detrimental influence on student academic performance. Particularly, the lecture, a teaching technique conventionally employed in

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higher education for large groups, bears a negative impact on student achievement lecture (Freeman et al., 2014).

New teaching methods have recently emerged in anatomy education that focus on learning and allow for modeling, such as the ORDER method—observe-reflect-draw-edit-repeat (Backhouse et al., 2017). This method involves a cyclical process that integrates cognitivist and constructivist learning theories, emphasizing critical observation, reflection, and drawing. It includes the following steps: (1) critical observation of the anatomy; (2) visualization and reflection on the observed anatomy; (3) drawing the observed anatomy; (4) reflection, discussion, and revision of the drawing; and (5) repetition and application of the acquired knowledge to new contexts. Through this process, the interplay of reflective observation, representation through drawing, and collaboration in the teaching process allows students to explore diverse perspectives and co-create models, thereby playing a fundamental role in developing anatomical knowledge (Backhouse et al., 2017).

Gamification, on the other hand, is a method that applies elements of video game design in non-game contexts, such as the classroom, to enhance psychological factors like motivation and the overall classroom climate (Deterding et al.,; 2011; López-Jiménez et al., 2021). These elements include feedback, challenges, social sharing, rewards, leaderboards (rankings), points, tips, levels, avatars, and badges. To implement gamification, educational technology is frequently used (Castellano et al., 2024), such as ClassDojo (DiGiacomo et al., 2022; Pratista, 2023).

In Spain, there is a notable prevalence of psychological distress among first-year university students (Arias-de la Torre et al., 2019), with a moderate prevalence of symptoms related to depression, anxiety, and stress (Ramón-Arbués et al., 2020). Academic stress is a prevalent issue among university students that holds international significance, as it diminishes students' well-being and leads to adverse effects on their health and academic performance (Pascoe et al., 2019).

To promote greater psychological well-being and overall health (Delgado et al., 2022; Tan et al., 2023; Van der Kaap-Deeder et al., 2020), while also enhancing learning outcomes, motivation, and the overall educational experience (Kusurkar et al., 2011), the basic psychological needs theory (BPNT) provides formal propositions stating that the satisfaction of three fundamental needs—autonomy, competence, and relatedness—leads to enhanced well-being and performance outcomes (Ryan et al., 2022). Autonomy involves a sense of volition and psychological freedom; competence reflects feelings of mastery and effectiveness, and relatedness entails a connection with others.

Autonomy frustration refers to personal experience of deprivation of volition and psychological freedom, and it is based on the disappointment of the desire to experience an internal "locus" of causality (to feel the origin of one's actions). The subject may think "I don't decide" or "it's not up to me." Research has shown that autonomy frustration not only correlates with feelings of helplessness but can also undermine intrinsic motivation, making students more likely to disengage from challenging academic tasks (Ryan et al., 2022). Competence frustration refers to the feelings of failure and doubts about one's efficacy. The subject could think "I can't" or "I couldn't achieve it." Relatedness frustration involves the experience of relational exclusion and loneliness. The subject may think "I can't be successful in the social or collaborative field" (Chen et al., 2015). A sense of relatedness frustration has been associated with emotional withdrawal from group learning and increased social anxiety, which in turn affect collaborative learning potential and classroom participation (Ryan et al., 2022). Competence frustration, as described by BPNT, predicts heightened stress responses and impairs cognitive processing abilities, both of which can negatively impact academic achievement in subjects that require intensive information processing, such as anatomy (Ryan et al., 2022). A person may feel, as a whole, perceived frustration on basic psychological needs, associated with feelings of disappointment, anger, disillusionment, or failure. However, there may be different effects on each of the subvariables (Longo et al., 2014).

BPNT also establishes that the frustration of these needs can predict ill-being and maladaptive outcomes (Deci & Ryan, 2000), which are manifested through constructs like Basic Psychological Needs Frustration (BPNF), a recognized contributor to psychological distress and diminished functioning (Ryan & Deci, 2017). Thus, the constructs of satisfaction and frustration should be considered distinct yet interrelated, as the former promotes growth and wellness, while the latter leads to experiences of ill-being and compromised academic engagement (Longo et al., 2018; Ryan et al., 2022).

In a recent meta-analysis, Ryan et al. (2022) further confirmed that BPNS is directly associated with adaptive outcomes, such as enhanced academic performance and psychological resilience, while BPNF has been consistently linked to outcomes like burnout, anxiety, and reduced academic motivation. This theoretical distinction highlights that simply preventing need frustration may not be sufficient; rather, actively fostering need satisfaction is essential for optimizing student well-being and academic engagement in learning contexts like anatomy education. Additionally, research has shown that BPNF can exacerbate negative affect and internalized pressures, leading to defensive or avoidant learning behaviors, whereas BPNS is associated with curiosity-driven and self-determined engagement in academic tasks (Ryan et al., 2022).

This BPNT is a sub-theory of the self-determination theory (SDT), which serves as a theoretical framework

addressing human motivation and personality. According to this theory, motivation and basic psychological needs are influenced by factors within the social context and the personal biography of the individual, including sports habits (Ryan & Deci, 2017, pp. 561–566). This theory has undergone extensive exploration within university education contexts (Ryan & Deci, 2000b) and specifically within the field of anatomy teaching and learning (Delgado et al., 2022; Tan et al., 2023; Willoughby et al., 2024). Frustration stemming from these three needs can act as an indicator of unfavorable outcomes, triggering negative states like distress, depression, and anxiety (Bartholomew et al., 2011), which subsequently exert a negative influence on student achievement (Buehner, 2017; Erzen, 2017). The frustration of these three needs has been demonstrated to predict the emergence of depressive symptoms in university students. Significantly, research has emphasized that feelings of ill-being or distress, primarily arising from experiences of need frustration rather than solely from a lack of need fulfillment (Longo et al., 2016), have been demonstrated to predict reduced academic performance (Tape et al., 2021). In a recent study (Longo et al., 2018), supplementary evidence was provided to reinforce the notion that need satisfaction and need frustration are distinct constructs. Additionally, the satisfaction and frustration subscales for each need could be considered separately, as they might have unique effects that should be explored (Liga et al., 2020).

Frustration, defined as a combination of anger and disappointment, has been shown to exert a negative impact on students' academic achievement (Camacho-Morles et al., 2021).

As previously mentioned, the frustration of basic psychological needs negatively impacts students' learning processes, thus emphasizing the essentiality of research in this area (Tindall & Curtis, 2019). As one delves into the extant literature, a noticeable gap emerges in the exploration of pedagogical strategies directly addressing the frustration of basic psychological needs within the context of anatomical education. Few studies concerning this variable have been identified, and those that have primarily focused on domains such as physical activity or sports (Li et al., 2021; Warburton et al., 2020), physical education (Warburton et al., 2020; Zamarripa et al., 2020), workplace dynamics (Busque-Carrier et al., 2022; Niemiec et al., 2022), self-critical perfectionism and eating disorders (Boone et al., 2014; Campbell et al., 2018), depression (Campbell et al., 2018; Levine et al., 2022; Pietrek et al., 2022), and other psychological concerns (Wei et al., 2021). Generally, the literature consists of publications focused on the validation of scales that measure the frustration of basic psychological needs (Chung et al., 2020; Liga et al., 2020; Olafsen et al., 2021; Tindall & Curtis, 2019; Zamarripa et al., 2020). Furthermore, although some studies concerning high school education have been identified (Zhang & Jiang, 2023), investigations specifically within university-level education remain scarce and often pertain to contexts related to the COVID-19 pandemic (Dasinger & Gibson, 2022; Levine et al., 2022) or address other challenges and disorders, such as attention deficit hyperactivity disorder (Serrano et al., 2023). Notably, no studies have been located that address the frustration of psychological needs within the domain of university-level anatomy teaching. Experimental research in anatomical education is also limited, primarily focusing on the evaluation of techniques and educational materials, such as virtual resources (Hopkins et al., 2011).

This article aims to bridge this research gap by introducing a multimodal educational design grounded in gamification, drawing, reflection, and collaborative teamwork. This design is intended for the instruction of human anatomy to first-year students in the field of Sports Science. The purpose was to expand scientific knowledge on how to mitigate students' frustration associated with the basic psychological needs of autonomy, competence, and relatedness, with the goal of enhancing students' anatomy learning experiences.

Multimodal methods in higher education have garnered endorsement from the literature (Abu Bakar et al., 2022; Sugand et al., 2010) due to their superior efficacy compared to singular methods, resulting in greater student satisfaction and engagement (Anderton et al., 2016; Bergman et al., 2013; Diaz & Woolley, 2015). Additionally, gamification (Krishnamurthy et al., 2022), facilitated by the ClassDojo educational platform (Pratista, 2023), can indeed yield a positive impact on learning, given its intrinsic connection to variables which have been shown to positively influence student achievement, such as motivation (Waluyohadi, 2019), enjoyment (Camacho-Morles et al., 2021; Loderer et al., 2020), and feedback (Lysakowski & Walberg, 1982) provided via quiz-based games (Ismail et al., 2019) or gamified response systems (López-Jiménez et al., 2021). Moreover, questioning (Gayle et al., 2006) and creativity (Gajda et al., 2017), along with techniques such as drawing to support anatomical learning (Amin, 2020; Backhouse et al., 2017; Greene, 2018; Naug et al., 2016), collaborative learning (Ravinder Kumar, 2017), and collaborative learning mediated via Information and Communications Technologies (ICT) (Borokhovski et al., 2016; Jeong et al., 2019), have also demonstrated a positive impact on student achievement. Collectively, this body of evidence lends robust support to the design we propose in our study.

The aim of this study was to assess the effects of a gamified creativity-based educational intervention for human anatomy on BPNF: autonomy frustration (AF), competence frustration (CF), and relatedness frustration (RF). The hypotheses (H) posited that the gamified creativity-based teaching method would result in lower BPNF compared to the conventional teaching method (H_1). Additionally, the

study aimed to examine the effects of the intervention on each of these variables individually: AF (H_2), CF (H_3), and RF (H_4).

Methods

Study Design

To test our hypotheses, we conducted a quasi-experimental study using pre- and post-measures, which involved both an experimental and a control group. This research design ensures significant internal validity while preserving the authenticity of educational activities and, subsequently, enhances external validity.

Participants

Our sample included 116 first-year students majoring in physical activity and sport sciences at two Spanish public universities from Spain. Among them, 60 were from the University of Zaragoza (12 women, 46 men), with an average age of 18.65 (SD = 1.25), and received the experimental treatment in Huesca city. Additionally, 56 students were from the University of Lleida (13 women, 43 men), with an average age of 19.38 (SD = 2.47), and received the control treatment in Lleida city.

Participation in the study was voluntary, and all participants provided informed consent after we explained the study's objectives. Ethical approval was granted by the Ethical Committee of Clinical Research of Aragon (Spain) on September 7, 2022 (PI22/383).

Procedure

In the Bachelor's Degree in Physical Activity and Sport Sciences programs at both universities, a mandatory human anatomy course is offered during the inaugural semester. Both treatments lasted for 30 h, spanning 7 weeks, and were part of the human anatomy curriculum, overseen by separate instructors at each university. While both covered general anatomy, anatomical position, axes, and planes, different human body systems were taught due to curricular constraints.

To investigate if gamification and creativity-based anatomy teaching produced lower frustration related to basic psychological needs in anatomy learning compared to the conventional teaching method, we implemented an experimental treatment based on gamification's mechanical-dynamic-aesthetic framework (Hunicke et al., 2004) and creativity teaching strategies using the ORDER method (Backhouse et al., 2017) (observation, reflection, drawing, editing, and repetition). This intervention incorporated visual elements for problem presentation and prompted questions. It included individual anatomical process drawing, group drawing and editing, quiz games for reinforcement, and the repetition of drawing assignments at home. Additionally, gamification was introduced through the ClassDojo platform, where instructors awarded points based on pre-designed categories (Fig. 1) to align with educational feedback principles (Hattie & Clarke, 2018; Hattie & Timperley, 2007), aiming to mitigate frustrations related to autonomy, competence, and relatedness (Table 1).

In the control treatment, the instructor independently selected teaching methods for human anatomy, without any researcher intervention. This primarily involved traditional lecture-style instruction and common resources like digital and physical atlases, note-taking, and drawing, without adhering the ORDER sequence or promoting reflective representation of processes. Notably, gamification was not integrated into this control treatment. The control treatment aimed to replicate a conventional anatomy teaching method (Table 1).

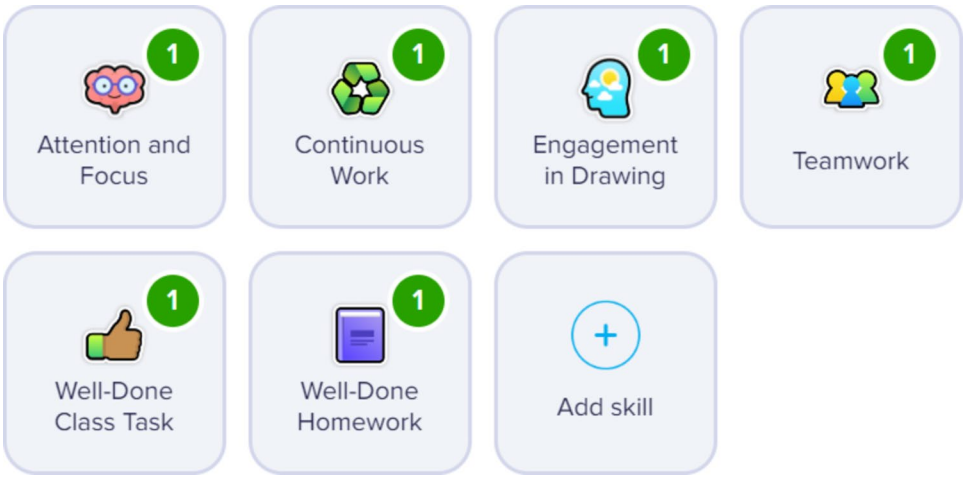

Fig. 1 Points categories in ClassDojo. Source: author's creation using ClassDojo

Table 1 Description of the educational-experimental treatment

	Treatment group	Control group
Degree program	Physical activity and sports sciences	Physical activity and sports sciences
Course level	First-year, semester 1	First-year, semester 1
Subject	Anatomical, kinesiological, and biomechanical fundamentals in physical activity and sports (content block, anatomy)	Applied anatomy in physical activity and sports
Implemented method	Researcher-controlled instruction: - Modeling through ORDER (observation-reflection-drawing-editing-repetition) - Gamification via a point system using ClassDojo and weekly interactive quizzes with Quizizz	Natural instruction not controlled by researchers: - No ORDER - No gamification
Group structure	- Full group: 80 students - Small groups: 4 groups of 20 students each	Full group: 120 students Small groups: 4 groups of 30 students each
Content	- General anatomy (anatomical terminology, anatomical position) - Planes and axes - Cardiovascular, respiratory, digestive, and nervous systems	General anatomy (anatomical terminology, anatomical position) - Planes and axes - Locomotor system (osteology, arthrology, and myology)
Evaluation instruments used	1. Mandatory continuous work notebook 2. Pre- and post-knowledge assessment through drawing of systems and organs 3. Theoretical-practical exam: - Multiple-choice questions - Reasoning questions: identification and delimitation of structures, practical application, explanation, and process drawing	1. Voluntary group projects (explanation of a movement, with freedom in resource selection) 2. Practical oral assessments 3. Theoretical multiple-choice exam
Intervention duration	30 h (7 weeks)	30 h (7 weeks)

Measures

Participants used a 5-point scale (1 = strongly disagree, 5 = strongly agree), to rate 12 items from the validated Spanish version of the Basic Psychological Need Scale (Chen et al., 2015). Only the frustration items from the Chen et al. (2015) questionnaire were used. These items gauged perceived frustration in basic psychological needs, categorized into autonomy, competence, and relatedness, with four items in each category. Data was collected both before (September 2022) and after the intervention (November 2022). To gain reliability in the instrument, two different indices were used, Cronbach's alpha and McDonald's omega (Hayes & Coutts, 2020; McDonald, 1999). Cortina (1993, p. 102) stated that if the number of a construct`s items is greater than 10, a Cronbach's alpha greater or equal to 0.7 is preferred. However, if the number of a construct`s items is smaller than 10, a Cronbach's alpha greater than 0.5 is preferred.

AF was composed of four items, for example "In my studies, I feel forced to do many things I wouldn't choose to do," and it demonstrated good internal consistency (in this study: $\alpha = 0.735$, $\Omega = 0.741$). RF was composed of four items, for example "In my studies, I feel excluded from the group I want to belong to," and it demonstrated sufficient internal consistency ($\alpha = 0.626$, $\Omega = 0.632$). CF was composed of four items, for example "In my studies, I have serious doubts about whether I can do things well," and it demonstrated a good internal consistency ($\alpha = 0.802$, $\Omega = 0.811$). BPNF was composed of 12 items, and it demonstrated strong internal consistency (Cronbach's $\alpha = 0.839$, McDonald's $\Omega = 0.837$).

Measures on biography or sports habits were also collected: sex, height, high school background, future career intentions, and specific sports practiced. These measures served as covariates that could be relevant to the main psychological variables (Ryan & Deci, 2017).

Statistical Analyses

We assessed normality and homogeneity and removed outliers for each variable. Then, we conducted independent samples *t*-tests to compare baseline group differences.

After the intervention, we used independent samples *t*-tests, and one-way ANCOVAs controlling for relevant covariates and pre-measure variables, to assess effects, calculating effect sizes using Cohen's *d* and partial eta-squared (η^2_p). The following interpretation of the effect sizes in educational research has been followed: small ($d \geq 0.2$), medium ($d \geq 0.5$), and large ($d \geq 0.8$) (Cohen, 1988); small ($d \geq 0.0099$), medium ($d \geq 0.0588$), and large ($d \geq 0.1379$) (Cohen, 1988, pp. 278–280; Richardson, 2011).

The relevance of the contemplated covariates for each variable was determined by a previous analysis of bivariate

correlations (Cohen's *r*); subsequently, these were added to the ANCOVAs to neutralize their effects.

In the study, we employed a factorial repeated measures ANCOVA 2 × 2 (time × treatment), comparing two groups based on time (baseline vs. follow-up) and treatment (control vs. experimental). This analysis comprehensively examined the effects of time and treatment on study variables. The graphs in the study were based on these a factorial repeated measures ANCOVA 2 × 2 (time × treatment). Effect size was calculated using η^2_p. Significance was set at $p \leq 0.05$. All analyses were performed using IBM SPSS Statistics 26.0 for Windows (IBM Corp, Armonk, NY).

Results

Descriptive statistics, including baseline and follow-up means and standard deviations for each dependent variable, can be found in Table 2. No statistically significant baseline differences were found between the two groups for the variable BPNF ($p = 0.33$), AF ($p = 0.72$), and CF ($p = 0.053$). However, there were baseline statistical differences found for the variable RF (t (114) = 1.12, $p = 0.03$; MD = 1.02 [95% CI, 0.09 to 1.94]), with a small effect size ($d = 0.4$).

Basic Psychological Needs Frustration

A post-intervention *t*-test for independent samples revealed a lower BPNF in the experimental treatment than control treatment (t (108) = 3.74, $p < 0.001$; MD = 3.99 [95%, 1.87 to 6.11], with a medium effect size ($d = 0.68$).

An ANCOVA, controlling the pre-measurement, revealed a lower BPNF in the experimental treatment than control treatment (F (1) = 9.666, $p = 0.002$; MD = 2.70 [95% CI, 0.979 to 4.43], $R = 43.9\%$), with a medium effect size ($\eta^2_p = 0.083$).

An ANCOVA, controlling for statistically relevant covariates for BPNF variable (sex, height, student's status as professional athlete, football habit, tennis habit, and fitness habit) and the pre-measurement, revealed a lower BPNF in the experimental treatment than control treatment (F (1) = 8.801, $p = 0.005$; MD = 2.48 [95% CI, 0.761 to 4.196], $R = 48.2\%$), with a medium effect size ($\eta^2_p = 0.077$).

A factorial repeated measures ANCOVA 2 × 2 showed a treatment main effect on BPNF (F (1) = 9.058, $p = 0.003$; MD = 3.10 [95% CI, 0.991 to 5.224], with a medium effect size ($\eta^2_p = 0.083$).

However, no time main effect ($p = 0.53$) and no interaction effect ($p = 0.12$) were found.

As a result, H_1 was supported: the experimental treatment is associated with lower levels of BPNF in students compared to the conventional treatment. Additionally, there are non-statistically significant indications of an increase in frustration in the conventional treatment, as opposed to a decrease in frustration in the experimental treatment (Fig. 2).

Autonomy Frustration

A post-intervention *t*-test for independent samples revealed no statistically significant differences in AF between the experimental treatment and control treatment ($p = 0.18$).

Coupled with two separate ANCOVAs, one controlling for the pre-measurement ($p = 0.18$), and the other adjusting for covariates, including students' status as professional athletes, fitness habits, and their future career intentions (teacher, coach, sports manager, or healthcare professional), along with the pre-measurement ($p = 0.14$), no statistically significant differences in AF were observed between the experimental treatment and control treatment.

A factorial repeated measures ANCOVA 2 × 2 revealed a significant time main effect on AF (F (1) = 6.02, $p = 0.016$; MD = 0.6 [95% CI, 0.12 to 1.08]), with a small effect size ($\eta^2_p = 0.053$). For better interpretation, we conducted a one-way ANCOVA separately for the control and treatment groups. This analysis showed no significant time effect in the treatment group ($p = 0.41$), while a significant time effect was observed in the control group (F (1) = 7.20, $p = 0.01$; MD = 0.91 [95% CI, 0.23 to 1.59]), with a medium effect size ($\eta^2_p = 0.126$). So, AF significantly increased in the control group, while it remained consistent over time

Table 2 Descriptive statistics: Basic Psychological Needs Frustration in pre- and post-control and experimental treatments

Variable	Control treatment		Experimental treatment	
	Baseline	Follow-up	Baseline	Follow-up
Basic Psychological Needs Frustration	24.02 ± 6.60 ($n = 56$)	25.14 ± 6.25 ($n = 56$)	21.64 ± 5.76 ($n = 54$)	21.14 ± 4.81 ($n = 54$)
Autonomy frustration	8.36 ± 2.58 ($n = 55$)	9.27 ± 3.60 ($n = 55$)	8.33 ± 2.33 ($n = 58$)	8.62 ± 2.57 ($n = 58$)
Competence frustration	8.61 ± 2.81 ($n = 56$)	8.68 ± 2.88 ($n = 56$)	7.60 ± 2.67 ($n = 57$)	7.35 ± 2.67 ($n = 57$)
Relatedness frustration	7.00 ± 2.70 ($n = 56$)	7.04 ± 2.27 ($n = 56$)	5.67 ± 1.75 ($n = 56$)	5.91 ± 1.84 ($n = 56$)

Data are presented as mean ± standard deviation (n = number of participants after eliminating outliers)

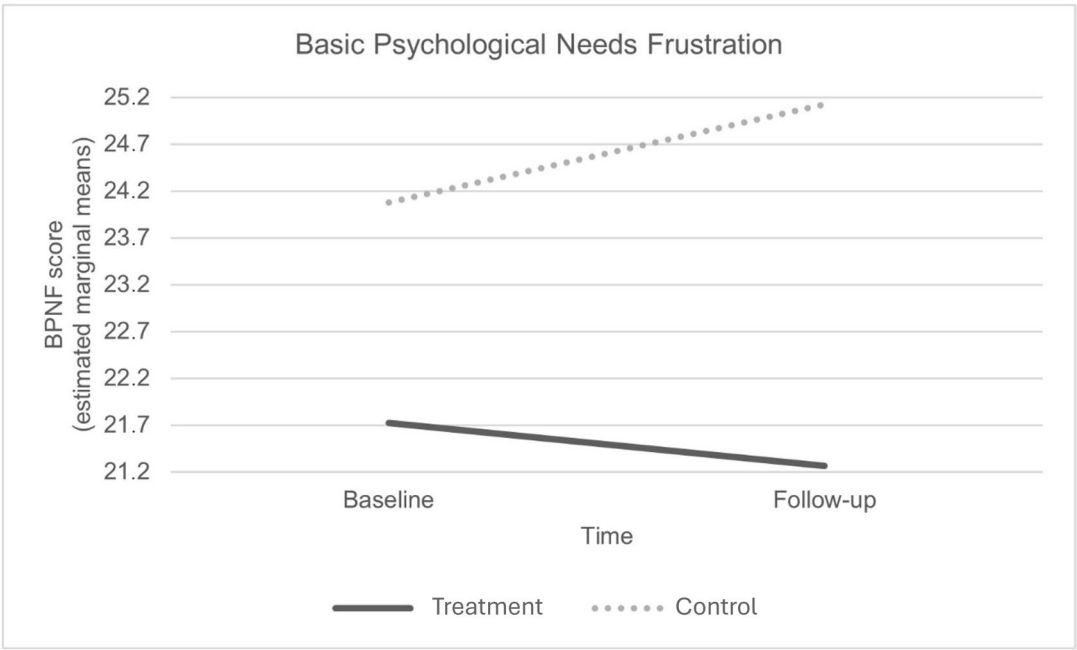

Fig. 2 Line graph (7 weeks) depicting the estimated marginal means of variable BPNF in both treatment conditions over time as analyzed through a factorial ANCOVA

in the treatment group. However, no treatment main effect ($p = 0.29$) and no interaction effect ($p = 0.24$) were found in the 2 × 2 factorial ANCOVA.

Thus, H_2 was not supported: the experimental treatment did not result in lower AF in students compared to the conventional treatment. However, a statistically significant increase in frustration was observed in the control group, whereas within the treatment group, a non-statistically significant increase in frustration was noted, suggesting a possible deceleration in the rise of frustration within this group (Fig. 3). This is an indication of a trend, and further research with an extended duration of the intervention would be necessary to explore whether the experimental treatment could potentially act as a protective factor against increasing frustration (Jaccard, 1998).

Competence Frustration

A post-intervention *t*-test for independent samples revealed a lower CF in the treatment group than the control group ($t(111) = 1.96$, $p = 0.012$; MD = 1.01 [95%, 0.12 to 2.03], with a small effect size ($d = 0.47$).

No statistically significant differences in CF were observed between groups using two separate post-intervention ANCOVAs. The first ANCOVA controlled for the pre-measurement ($p = 0.076$), while the second ANCOVA controlled for covariates known to impact the CF variable, including students' status as professional athlete, their volleyball habits, prior academic performance, and prior study of anatomy, in addition to the pre-measurement ($p = 0.11$).

A factorial repeated measures ANCOVA 2 × 2 revealed no time main effect ($p = 0.64$), no treatment main effect ($p = 0.61$), and no interaction effect ($p = 0.11$) on CF. We conducted a one-way ANOVA separately for the control and treatment groups. This analysis showed no significant time effect in the treatment group ($p = 0.779$), while a significant time effect was observed in the control group ($F(1) = 4.55$, $p = 0.041$; MD = 0.78 [95% CI, 0.04 to 1.53]), with a medium effect size ($\eta^2_p = 0.125$). Therefore, while CF significantly increased in the control group, it remained consistent over time in the treatment group (Fig. 4).

Despite these results and the fact that some of the analyses showed a lower CF after the experimental treatment compared to the control group, with a small effect size, it is important to note that this decrease cannot be solely attributed to the treatment. The covariates considered in the CF analysis hold significant importance, as the treatment's effect ceases to be statistically significant when these covariates are considered. Therefore, H_3 was not supported: the experimental treatment did not result in lower CF in students compared to the conventional treatment. However, it is worth noting that a statistically significant increase in frustration was observed in the conventional treatment, while a non-statistically significant decrease in frustration was observed in the experimental treatment. Based on the observed trend (Fig. 4), it could be inferred that the experimental treatment

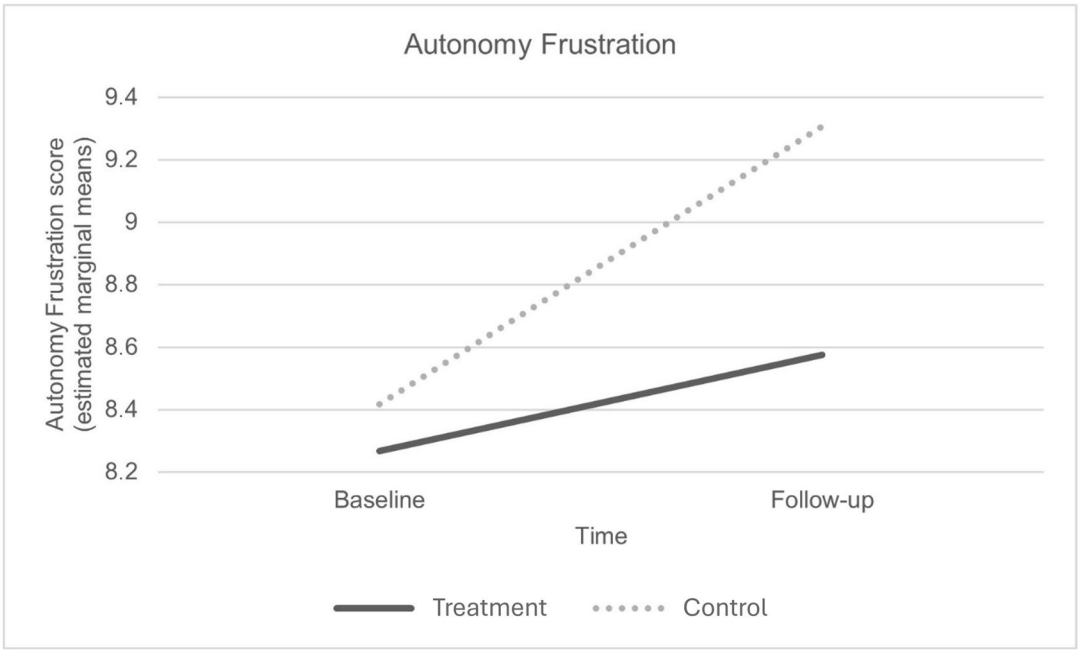

Fig. 3 Line graph (7 weeks) depicting the estimated marginal means of autonomy frustration in both treatment conditions over time as analyzed through a factorial ANCOVA. The increase in frustration in the control group is statistically significant; in the treatment group, it is not statistically significant

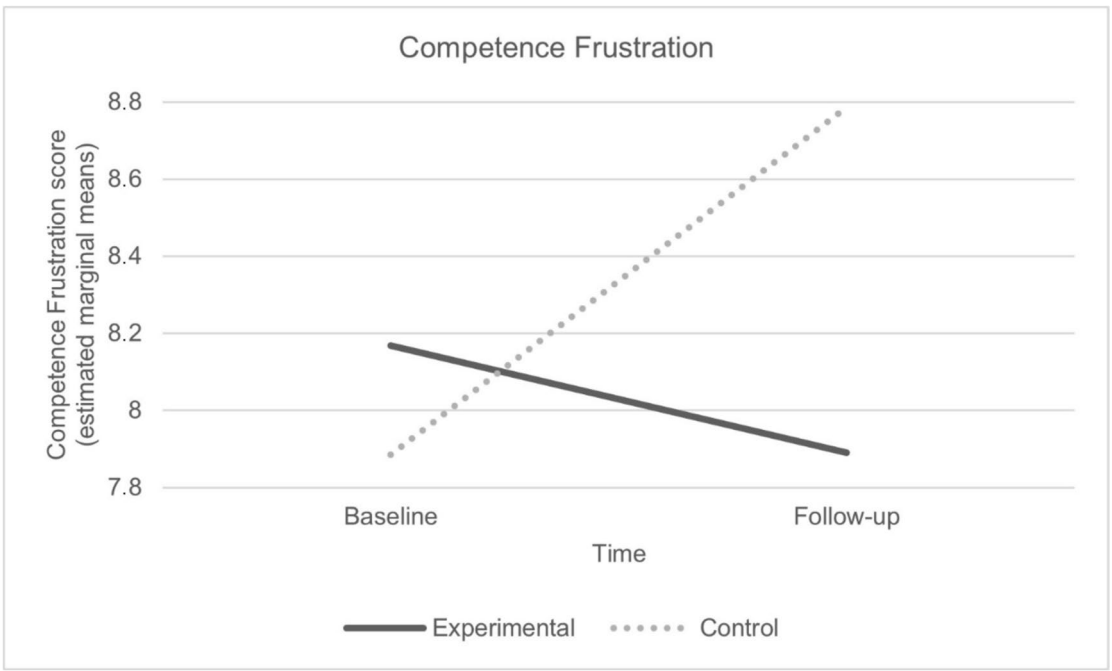

Fig. 4 Line graph (7 weeks) depicting the estimated marginal means of competence frustration in both treatment conditions over time as analyzed through a factorial ANCOVA

could be acting as a protective factor against competence frustration (Jaccard, 1998). Further research is needed to better understand this phenomenon and whether extending the experimental treatment duration may reduce frustration.

Relatedness Frustration

A post-intervention *t*-test for independent samples revealed a lower RF in the experimental treatment than the control treatment (t (110) = 2.88, p = 0.005, MD = 1.13, [95% CI, 0.35 to 1.90]), with a larger effect size (small effect size, d = 0.53) compared to the baseline differences (small effect size, d = 0.40).

No statistically significant differences in RF were observed between groups when analyzed using two separate ANCOVAs, one controlling for the pre-measurement (p = 0.29), and the other controlling for covariates known to impact the RF variable, including students' status as professional athletes, height, high school background, practicing sports such as tennis, paddle, athletics, or hockey, along with the pre-measurement (p = 0.22).

A factorial repeated measures ANCOVA 2 × 2 (time × treatment) revealed a significant treatment main effect on RF (F (1) = 7.28, p = 0.008, MD = 1.06, [95% CI, 0.28 to 1.84]), with a medium effect size (η^2_p = 0.069). However, no time main effect (p = 0.66) and no interaction effect (p = 0.11) were found on RF.

While a significant difference in RF was evident between the groups at baseline, the effect size was smaller than what was observed between the groups in the post-measurement (Fig. 5). It is important to note that a significant treatment effect was observed, but it may be explained by the baseline differences. Therefore, H_4 was not supported. On the other hand, the absence of time main effect could be explained by the duration of the intervention. The data suggest that there could be potential effects in future studies if the duration of the intervention is prolonged.

Discussion

This study aimed to investigate whether the incorporation of a multimodal human anatomy education method based on creativity and gamification could result in lower frustration of basic psychological needs (autonomy, competence, and relatedness) compared to a conventional teaching method in a similar academic context. Our study identified a treatment effect, showing that creativity- and gamification-based education resulted in lower frustration of total basic psychological needs compared to conventional teaching methods. This aligns with previous research (Anderton et al., 2016; Bergman et al., 2013; Diaz & Woolley, 2015) that, while examining satisfaction rather than frustration, has reported that multimodal teaching approaches are associated with higher levels of student satisfaction and engagement compared to traditional methods of teaching anatomy. Additionally, gamification has been previously associated with intrinsic motivation (Suh et al., 2018), which is linked with enhanced conceptual understanding, improved learning, and greater academic performance and achievement, as well as higher levels of well-being (ten Cate et al., 2011). Reducing frustration can contribute to improved student learning, as negative emotions have been associated with lower participation in learning (Reschly et al., 2008) which is necessary for achievement and affects academic performance in higher education (Rickwood et al., 2017).

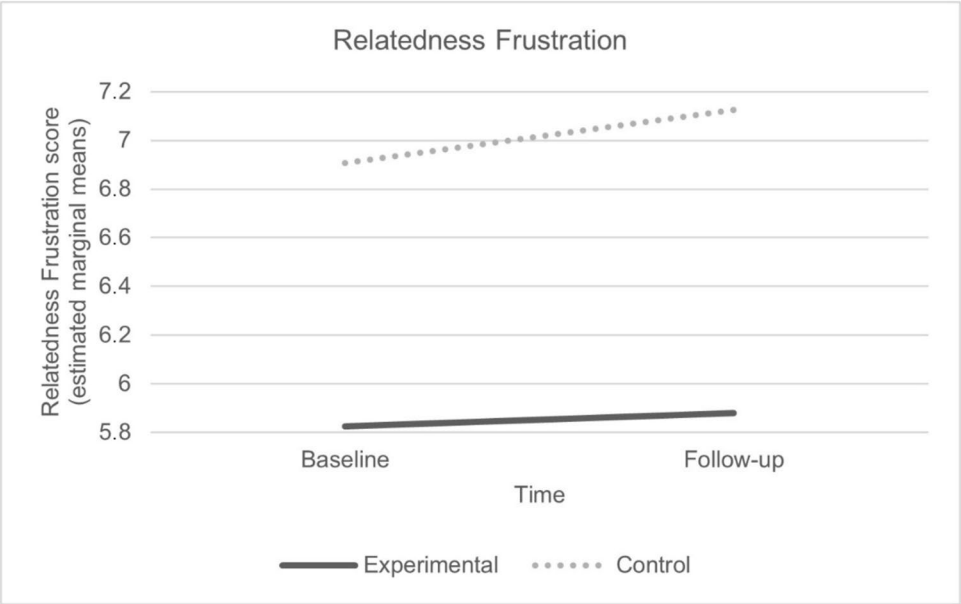

Fig. 5 Line graph (7 weeks) depicting the estimated marginal means of relatedness frustration in both treatment conditions over time as analyzed through a factorial ANCOVA

Furthermore, this study revealed that over a 7-week period, the experimental treatment maintained the AF level, whereas in conventional anatomy classes, this variable increased. However, there were indications of a potential increase in AF (non-statistically significant) within the experimental treatment, suggesting a possible deceleration in the rise of frustration. To fully understand this phenomenon, the effects of a longer intervention need to be studied.

This deceleration could be attributed to factors such as the introduction of a rewards system and self-expression activities in the experimental treatment. Both rewards, in the form of points awarded by the teacher and informative feedback (Deci et al., 1999), and self-expression, whether through customizing avatars (Suh, 2015; Suh et al., 2018) or creating their own drawings, have previously been shown to enhance autonomy (Suh et al., 2018). Moreover, in the experimental treatment, students voluntarily engaged in classroom discussions and reflections, demonstrating autonomy (Lujan & DiCarlo, 2017). These combined strategies could explain why this gamified creativity-based method seems to slow down or mitigate the increase in autonomy frustration. For anatomy educators, implementing the ORDER method in practical anatomy sessions could encourage students' reflective engagement, as it allows them to iteratively draw and conceptualize anatomical structures, which has shown benefits for understanding complex spatial relationships. It would be equally relevant to consider as covariates the psychological profile of the participants, such as the ambivalent or sufficiently satisfied profile extracted in the study of Reed-Fitzke and Lucier-Greer (2021). Nevertheless, further research is needed to validate these findings.

Additionally, the experimental educative design demonstrated the potential to act as a protective factor, potentially averting an increase in CF or even displaying a trend toward reducing it. These findings can be partly attributed to the utilization of ClassDojo points as rewards for classroom tasks within the experimental treatment. This approach, which is based on a reward system, promotes a recurring sense of achievement, thereby enhancing self-esteem and positively influencing the sense of competence (Przybylski et al., 2010; Suh et al., 2018). Additionally, this rewards system also included quiz games, which create a competitive environment that motivates individuals to strive for better performance and strengthens their sense of competence (Ryan & Deci, 2000a; Suh et al., 2018). Quiz games integrated into gamified experience have been found to improve performance and participation in anatomical sciences in higher education (Wilkinson, 2017), and they serve as predictors of academic performance among anatomy students (Alexander et al., 2009; Garza et al., 2023). Using quiz-based platforms such as Quizizz in anatomy courses could serve as an ongoing assessment tool, allowing educators to identify areas where students struggle and provide targeted feedback. This interactive approach is valuable for complex subjects like anatomy, where continuous reinforcement aids memory retention. Moreover, they have also shown positive effects on student satisfaction, participation, and motivation (López-Jiménez et al., 2021). Thus, quiz games have previously been shown to motivate students to study and promote awareness of their progress in learning (Côrtes et al., 2022; Cortés-Pérez et al., 2023; Ismail et al., 2019). Furthermore, both quiz games and other techniques employed in the experimental treatment, such as drawings, have been shown to improve perceived engagement, self-confidence, and deep learning in students (Nicholson et al., 2016). All of these factors may account for a potential protective effect against competence frustration observed in the group that received the experimental treatment.

Moreover, the findings of this study hold theoretical significance for BPNT, as they empirically support the theory's formal propositions regarding the positive effects of basic needs satisfaction on academic engagement and well-being, as well as the negative effects of needs frustration on psychological health. By distinguishing between needs satisfaction and frustration as distinct yet interrelated constructs, the study contributes to a nuanced understanding of BPNT within educational settings. This distinction is particularly relevant to anatomy education, as fostering an environment that promotes needs satisfaction may not only reduce frustration but also enhance student engagement and intrinsic motivation, key factors for academic success in demanding subjects (Deci & Ryan, 2000; Ryan et al., 2022).

Finally, although a significant main treatment effect with a medium effect size was found in RF, this could be partially explained by the initial differences between both groups. Furthermore, competition (inherent in the quiz games used in the experimental treatment) fosters interactions among individuals (Suh et al., 2018), and students feel more engaged (Laura De La Cruz et al., 2021). Moreover, public recognition through ClassDojo could have promoted a positive classroom environment and collaboration among students in the experimental treatment, in line with previous literature (Pratista, 2023). By incorporating these gamified recognition tools, anatomy instructors can cultivate a classroom atmosphere that not only rewards achievement but also encourages peer collaboration, an essential factor for professional health sciences. All of these factors might elucidate a potential protective effect against competence frustration in the group that underwent the experimental treatment (Lipscomb et al., 2018; Putrie et al., 2024). On the other hand, it is possible that a main time effect was not found due to the intervention's duration, suggesting potential effects in future studies with an extended duration.

Our research suggests that a multimodal approach to teaching human anatomy, incorporating a gamified creativity-based method, could effectively reduce the frustration

of basic psychological needs (autonomy, competence, and relatedness) compared to traditional lecture-style method. This suggests that integrating such innovative teaching strategies could foster a more supportive learning environment, by avoiding frustration of students' basic psychological needs. Educators and curriculum developers could benefit from these insights by incorporating gamified and creative elements into their teaching practices, which could avoid ill-being.

Furthermore, our findings have practical implications for enhancing anatomy education methods. Educators might implement gamification techniques, such as reward systems and interactive activities, to reduce frustration. In addition, policymakers could consider these approaches in curriculum design to promote a more engaging and inclusive educational experience. For example, implementing gamified feedback loops, like those in ClassDojo, and creative drawing tasks could enhance anatomy learning by keeping students actively engaged and allowing them to track their progress in mastering complex anatomical knowledge. Future research should explore the long-term effects of these methods and how they can be tailored to different educational contexts, thereby maximizing their benefits for student learning and development.

Limitations of the Study and Future Directions

The research was conducted at two different public universities, each with its own curriculum organization, in order to investigate two distinct treatments while adhering to ethical standards by administering a uniform treatment to all students from the same university. Therefore, it is advisable to explore the same content in future studies to mitigate potential variations in perceived difficulty between different anatomy systems, which could impact frustration levels.

A central challenge of this study is in distinguishing the unique contributions of each method—gamification and creativity teaching strategies using the ORDER method—within the multimodal educational intervention. Future research could benefit from comparing the effectiveness of each individual method to the multimodal approach, thereby providing a clearer understanding of their specific impacts on educational outcomes. Additional avenues for research may involve extending the intervention duration, as current results have indicated non-statistically significant trends in some variables.

Besides, this study's sample was limited to first-year students in the physical activity and sport sciences degree program, which may limit the generalizability of findings to other disciplines or educational levels. Future studies should consider testing the intervention across various health sciences or STEM fields, as well as among students at different stages in their education, to determine broader applicability.

Conclusion

In a population of students taking a human anatomy course as part of a bachelor's degree in physical activity and sports sciences, a gamified, creativity-based teaching method for human anatomy was associated with lower Basic Psychological Needs Frustration compared to business-as-usual anatomy instruction. However, when examining the individual variables of autonomy, competence, and relatedness needs, the study did not observe a significant reduction in frustration levels within the treatment group. It is worth noting, though, that there are indications of a deceleration in the increase of autonomy frustration and indications of a decrease in competence frustration in the treatment group, indicating that the experimental treatment may serve as a protective factor. Similarly, the observed treatment effect on relatedness may be attributable to baseline differences in this variable. Therefore, additional research is required to fully comprehend this phenomenon.

Recognizing the impact of negative psychological variables is essential for improving the quality of education. Understanding how these variables affect student learning allows educators and policymakers to implement strategies that support students' psychological needs and promote a positive learning experience. Our findings underscore the importance of developing and applying educational interventions that address these psychological factors, ultimately contributing to a more effective and equitable educational system.

This study employed a rigorous quasi-experimental design with both control and treatment groups, adhering to established scientific standards, including group comparisons and the use of reliable measurements as recommended in the scientific literature. It contributes to the limited body of evidence regarding the effectiveness of a human anatomy educational program within the context of physical activity and sport sciences. Further research and replication studies are necessary to strengthen the evidence supporting the gamified, creativity-based teaching method in anatomy education.

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Author Contribution LLN participated in the design of the study, carried out data collection, contributed to data analysis and interpretation of results, and drafted the manuscript. AQH participated in the design

and direction of the study, contributed to data collection, performed the statistical analysis, contributed to interpretation of results, and helped to draft the manuscript, as well as its critical revision. MJSB participated in the design and coordination of the study, contributed to data collection and interpretation of results, and helped to draft the manuscript, as well as its critical revision. All authors have read and approved the final version of the manuscript and agree with the order of presentation of the authors.

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Declarations

Ethics Approval and Consent to Participate Ethics approval was granted by the Ethical Committee of Clinical Research of Aragon (Spain) on September 7, 2022 (PI22/383).

Competing Interests The authors declare no competing interests.

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