Modeling physics identity profiles of freshmen physics students through person-centered analysis: relationships with gender, academic motivation, engagement, anxiety and intention to drop-out

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Research has thoroughly demonstrated that the intention to pursue a career in physics is influenced by the extent to which students perceive themselves as physics persons, or in other words, their physics identity. However, previous studies have mainly used variable-centered approaches to explore the relationship between identity and its precursors, which may hinder significant differences among subgroups within a sample. This study examines the profiles of undergraduate students based on their physics identity, as defined by a five-dimensional framework comprising self-perception, self-efficacy, interest, sense of belonging, and perceived recognition. We also investigate the role of gender, academic motivation, engagement, anxiety, and the intention to drop out in predicting profile membership. A convenience sample of 919 Italian undergraduate physics students (37.6% female identified students) participated in the study. Profiles were extracted using a novel approach combining Multiple Correspondence Analysis and Hierarchical Cluster Analysis. Analysis revealed five distinct identity profiles: 1. Enthusiast, 2. Committed, 3. Isolated, 4. Neutral, and 5. Disengaged. All covariates were significant predictors of membership of at least one profile. This study contributes to the growing body of research on physics identity by bridging a methodological gap between person-centered approaches and quantitative work on identity in physics education research.

Keywords: Physics identity, person-centered approaches, quantitative methods

I. INTRODUCTION

Recent studies have increasingly highlighted the pivotal role of physics identity—broadly defined as the process through which individuals perceive and define themselves in relation to the discipline of physics—in shaping students' educational trajectories and career aspirations [1-2]. Empirical evidence indicates that a robust physics identity among high school students is positively associated with their likelihood of pursuing physics at the tertiary level [3]. At the university stage, a strong identification with physics has been linked to greater persistence and sustained engagement in coursework [4], enhanced academic performance [5], and reduced dropout rates [6]. Moreover, when students have a strong sense of physics identity, they invest more in learning content since they highly value the consequence of such a behavior, thus maintaining the sustainability of the learning process [4]. Given these findings, a deeper understanding of physics identity at the undergraduate level is essential for elucidating the mechanisms that foster academic success and retention within Science, Technology, Engineering and Mathematics (STEM) fields as physics.

While most of previous studies used a variable-centered approach to investigate physics identity, we advocate for a person-centered approach to investigating physics identity, aiming to provide a more comprehensive and context-sensitive understanding of its development and implications. In the following sections, we first operationalize the physics identity construct by reviewing existing literature that explores its intersections with gender, academic motivation, engagement, anxiety, and dropout intentions. Then, we critically examine the methodological approaches employed in prior research, emphasizing the limitations of variable-centered analyses in capturing the nuanced experiences of diverse student subgroups in physics courses.

II. BACKGROUND

A. Conceptualizing Physics Identity

In this study, physics identity is conceptualized through an integrative framework that draws upon multiple theoretical perspectives. Central to our approach is Social Identity Theory [7] which posits that disciplinary identity constitutes a form of social identity, reflecting the degree to which individuals, using the reflexive aspect of the self, perceive themselves as members of a particular social group. Within the context of physics education, this entails both a sense of belonging to the physics community [8] and perceived recognition within that community [9-10]. Physics identity is thus understood as a dynamic construct shaped by ongoing personal and social negotiations which can lower perceived barriers and increase social support, as well as by individuals' perceptions of physics, physicists, and their own physics-related experiences [11-13]. Overall, the development of a student physics identity is a dynamic process that evolves over time, shaped by ongoing social interactions and the continuous reconstruction of personal meaning within the field [14-15].

Complementing this sociocultural lens, we incorporate insights from interest theory [16-17]. From this perspective, on the one hand, physics identity is sustained through individual's beliefs about the importance of personal interest towards a specific physics content and the utility of engaging in physics-related tasks [18], while, on the other hand, the development of interest for a particular physics content can be fostered by deciding whether a person identifies with that content or not [19].

Finally, we draw on Social Cognitive Career Theory [20], which highlights the predictive role of identity in career development within STEM fields. Within this framework, physics identity can be linked to self-efficacy beliefs, namely the beliefs in one's ability to handle specific physics tasks that are similar to previously encountered ones. Self-efficacy beliefs can predict student outcomes and persistence, thus contributing to expectations and career-related decision-making in physics [21-22]. In other words, early performance influences academic self-concept, which in turn influences future performance [23].

Building on these theoretical foundations and well-established empirical work in line with these pillars [24-25], we operationalize physics identity in this study through five interrelated dimensions: (1) *self-perception*, referring to how students view themselves in relation to the physics discipline; (2) *self-efficacy*, denoting beliefs about their ability to apply physics knowledge and solve physics-related problems; (3) *interest*, defined as a sustained psychological engagement with physics content; (4) *sense of belonging*, reflecting the degree of connectedness to the physics community; and (5) *perceived recognition*, indicating the extent to which students feel acknowledged by others, such as teachers or peers, as competent in physics.

B. Factors influencing Physics identity

A substantial body of research indicates that, compared to boys, girls tend to report a significantly lower sense of identity in STEM fields as physics [5, 21, 26-28]. This disparity suggests that a misalignment between girls' self-concept and their perception of themselves as physics learners may contribute to their underrepresentation in physics careers [25]. Specifically, when girls experience a perceived conflict between their gender identity and the physics identity, they are less likely to pursue physics-related careers [21]. This phenomenon is further supported by studies showing a negative association between identifying as female and participation in physics programs [24]. Additionally, implicit associations linking physics with masculinity or the "nerd-genius" stereotype have been found to diminish girls' identification with the subject [29]. Stereotype threat may also exacerbate this issue by increasing perceived social pressure in STEM contexts [30] or by undermining the perceived societal relevance and altruistic value of physics [31].

Conversely, the development of a strong disciplinary identity has been associated with positive academic outcomes, including increased persistence in undergraduate physics courses [32]. In this context, engagement has emerged as a key factor in promoting persistence and reducing dropout rates [33-36]. Engagement is typically defined as a proactive and positive orientation toward academic tasks, encompassing the quality of participation, investment, and commitment [37-38]. Prior research has also highlighted links between professional identity and specific dimensions of engagement, such as self-regulated learning [39]. Moreover, engagement in a particular course may foster students' identification with their institution and its values [40]. Importantly, engagement is embedded in social relationships and shared experiences, which can shape future aspirations and identification with professional roles [41]. Altogether, these findings suggest that engagement may be meaningfully associated with the development of a strong physics identity.

Identity is also closely linked to academic motivation, which drives a person's behavior in terms of the realization of three fundamental psychological needs: autonomy, competence, and relatedness [42-43]. These needs are closely related to four dimensions of physics identity. Specifically, high interest can satisfy the autonomy need, higher self-efficacy can satisfy the need of competence, while higher sense of belonging and recognition can satisfy the need of relatedness. Taking into account these relationships between identity dimensions and self-perception and adopting a model of motivation as a continuum [44], from self-determined reasons (*intrinsic motivation*) to less autonomous and external reasons (*extrinsic motivation*), it is reasonable to hypothesize that motivation may predict the individual's perception of the self as a physics person, namely that higher motivation leads to higher identification.

Finally, physics anxiety can significantly influence the development of disciplinary identity. Conceptualized as a multidimensional psychological construct, anxiety encompasses phenomenological, physiological, and behavioral responses to perceived threats of failure or negative evaluation in academic settings [45]. A typical conceptualization of anxiety includes components such as worry, emotionality, cognitive interference, and lack of confidence [46]. For instance, excessive worry and emotional distress can impair students' ability to engage confidently with physics tasks, thereby diminishing self-efficacy [47]. Cognitive interference may disrupt concentration and problem-solving abilities, weakening students' perceived competence. Similarly, a lack of confidence, often rooted in repeated negative academic experiences, can erode self-identification with physics and foster feelings of alienation from the discipline. Moreover, anxiety may reduce interest and sense of belonging, particularly among marginalized groups, reinforcing stereotypes and limiting recognition from instructors and peers [48]. Overall, such relationships suggest that elevated levels of physics anxiety may lower the perception of physics identity.

III. AIMS OF THE STUDY

Research on physics identity has predominantly used variable-centered methodologies, such as structural equation modelling, to examine the links between identity constructs and their antecedents or contextual influences [8-10, 49]. For instance, the studies in refs [24, 25] found that individuals' self-identification with physics is predicted by their interest, sense of recognition, and – indirectly – by their self-efficacy, and that the structural relationships in the model are moderated by gender. However, while these approaches have made significant contributions to physics identity research, they are inherently limited in their ability to capture heterogeneity within populations. Specifically, these approaches assume homogeneity in relationships across individuals and infer population-level trends from average values within a sample [50], thereby overlooking potential variations among subgroups within the sample [51]. Furthermore, the complexity of inter-variable relationships in these models can impede the derivation of clear, actionable insights for specific subpopulations. The common practice of identifying subgroups through means or median leads to further risks introducing sample-based bias [52].

In contrast, person-centered approaches—aligned with an ecological systems perspective—conceptualize individuals as integrated psychological, biological, and social beings [53]. These approaches emphasize identifying subgroups of individuals who exhibit similar patterns of attributes or inter-variable relationships within a given context [54-55]. By capturing this heterogeneity, person-centered methods offer a more nuanced understanding of individual differences and developmental trajectories [56]. Moreover, they provide a holistic perspective by simultaneously considering multiple variables, which is particularly valuable for interpreting complex behaviors [57]. Importantly, person-centered analyses are often more applicable in educational contexts, as they support the design of tailored interventions and support strategies for diverse student populations [58].

In summary, person-centered approaches provide an appealing alternative approach to examining physics identity. Specifically, these approaches enable researchers to classify individuals, such as undergraduates, based on their scores across multiple identity dimensions. These methods provide a distinct lens through which to examine how these dimensions interact within individuals rather than assuming uniform effects across a population, as is typical in structural equation modelling [59]. Furthermore, by identifying latent profiles, researchers can evaluate whether these groupings represent meaningful subpopulations and investigate the role of variables identified in the literature such those reviewed above as predictors of profile membership. Finally, using a person-centered approach it is possible to investigate hypothesized relationships between profile membership and relevant educational outcomes, as, e.g., persistence in or intention to drop-out from a physics degree course. While drop-out is a phenomenon that occurs in all scientific areas, it becomes a particular relevant problem for society and scientific progress when it concerns disciplinary areas characterized by high technological specialization as engineering or physics [60]. Moreover, since students' decision to drop-out represents a process gradually unfolding over time [61], it cannot be considered independently from the development of students' own disciplinary identity.

To the best of our knowledge, no study has adopted a person-centered approach to identify different physics profiles among undergraduate physics students, investigate the role of other non-cognitive variables in predicting membership in these profiles, and whether the profiles are associated with relevant academic outcomes as persistence in the chosen degree course. Therefore, this study aims to address these gaps in literature.

The following three research questions guided our study:

RQ1) Which identity profiles can be identified in a sample of first year university physics students?

RQ2) To what extent are the identified profiles associated with students' gender, academic motivation, engagement, and anxiety?

RQ3) To what extent is membership in the identified profiles associated with intention to drop-out?

IV. METHODS

A. Sample and procedure

A convenience sample of N = 919 physics freshmen students (37.6% female students) was involved in the study. About 65.5% attended a university located in the North of Italy, 10% a university in the Center, 25.5% a university in the South. There was a not significant association between gender and the three geographical regions ($p >> .05$). The gender distribution in our sample roughly corresponds to the average percentage across Italy for physics degree courses.

The data were collected during in-presence lessons in the second semester of the first year of the degree course. At that time, on average, most of the students had followed at least one calculus course and two physics courses, introductory mechanics and laboratory. All participants provided written informed consent prior to participation and were fully briefed on the handling of their data. Specifically, students were informed that their responses would have remained anonymous, that the data would be used exclusively for research purposes, and that all data would be stored in compliance with the General Data Protection Regulation (GDPR) 2016/679. The study was conducted in accordance with the ethical principles outlined in the 1964 Declaration of Helsinki and its subsequent amendments or equivalent ethical standards. Ethical approval for the research was granted by the Ethics Committee of the first and last authors' university (protocol number: PG/2024/0137296).

B. Measures

To measure physics identity in line with the adopted theoretical perspective, we used five scales for a total of 24 items adapted from already validated instruments taken from studies informed by the same theoretical perspectives of the present study. Specifically, the following scales were used:

- perception of the self as a physics person (PS-PHYS), four-item scale [62]. Example item: *Being good in Physics is an important part of who I am*
- self-efficacy in physics (SE-PHYS), ten-item scale [63]. Example item: *I am good at working out difficult Physics problems*
- student interest in physics (SI-PHYS), three-item scale [2]. Example item: *Topics in physics excite my curiosity*
- sense of belonging (SB-PHYS), three-item reversed scale [25]. Example item: *With respect to a physics community, to what extent do you feel alone or isolated?*
- perceived recognition (PR-PHYS), four-item scale [2]. Example item: *My friends or classmates see me as a physics person*

All scales used a 5-point Likert scale, with "1" indicating strong disagreement and "5" indicating strong agreement, except the SB-PHYS scale, for which "1" indicated *not at all* and "5" indicated *completely*.

Academic Motivation was measured using the Italian version of the Academic Motivation Scale (AMS) [64]. The AMS features 20 items on a 7-point Likert scale, from 1 (not corresponding at all) to 7 (totally corresponding). The scale has five sub-scales, each measuring one of the regulation styles of AM, namely (i) *intrinsic* and (ii) *identified* motivation, that refer to the most autonomous style of regulation, (iii) *introjected* and (iv) *external*, that refer to the least autonomous style of regulation, and (v) *amotivation* that refers to the lack of intention to act in any way.

Engagement was measured using the SInAPSi Academic Engagement Scale (SAES) [34]. The SAES is a 29-item self-report measure that evaluates engagement on 6 dimensions: *1. university value and sense of belonging; 2. university course value; 3. integration between university and relational net; 4. relationships with university peers; 5. relationships with university professors* and *6. perception of capability to persist in the academic choice*. Each scale uses a 5-point Likert scale, from 1 (not at all) to 5 (totally). For this study, we used only the first five scales, while the sixth scale was used to measure drop-out intention.

Anxiety towards physics was measured through the Physics Test Anxiety Inventory (PTAI) scale, developed and validated in a previous study [47]. The PTAI scale features 20 items and is organized into 4 sub-scales, each measuring one of the following dimensions: (i) worry; (ii) emotionality; (iii) interference; (iv) lack of confidence. The latter sub-scale featured 5 reversed items. For the present study, for homogeneity reasons with the identity and engagement scale, the original 4-point Likert scale was changed into a 5-point scale using the following modalities: *never*, *rarely*, *sometimes*, *often*, and *always.*

Drop-out intention was measured using the reversed sub-scale *perception of capability to persist in the academic choice* of the SAES instrument. The subscale features four items (e.g., *Sometimes I think about leaving university*).

Gender was measured using both a binary measure (gender at birth, 1 = female, 0 = male) and a nonbinary measure [65]. The nonbinary measure features six items on a 7-point Likert scale, from 0 = *not at all* to 6 = *very*. The six items are organized into two dimensions: (i) *self-identified femininity, masculinity, or androgyny* and (ii) reflected appraisal of femininity, masculinity, or androgyny. In this study, we used the nonbinary measure. Therefore, we will refer to female identified students and male identified students.

All the used scales are reported in the supplemental material.

C. Data Analysis

First, we deleted 60 cases (6.5%) with missing data for more than half of the questions on each scale. After performing a Little's missing completely at random (MCAR) test ($p = .132$) [66], we imputed the remaining missing values (ranging from 0.1 to 0.5%) using expectation maximization

(EM). Then, we performed the following preliminary analyses. More details are reported in the supplemental material.

We carried out a confirmatory factor analysis to support the validity of the 5-factor structure of the instrument to measure physics identity also for our sample. After removing five items with weak factor loading (< .50), all indices of the model fit were satisfactory [67]: χ^2/d.o.f. = 4.626, p < .001, RMSEA = 0.065, SRMR = 0.067, NFI = 0.91, IFI = 0.93, CFI = 0.93, TLI = 0.91. Average Variance Extracted (AVE) was greater than the 0.5 threshold (Fornell & Larcker, 1981) for each dimension: 0.53, 0.52, 0.51, 0.70, 0.51, respectively. Moreover, each AVE estimate was greater than the squared correlation estimates for any two dimensions of the scale (see Supplemental Material). McDonald's ω for each dimension was good: 0.80; 0.86; 0.87; 0.76; 0.75, respectively. Overall, our analysis confirms convergent and discriminant validity of the instrument, namely that the factors are well separated and measure different dimensions of the Physics identity construct.

Concerning the AMS, we calculated the Relative Autonomy Index (RAI), which is obtained using the following formula [68]:

$$RAI = 2*\overline{(\text{intrinsic})} + 1*\overline{(\text{identified})} - 1*\overline{(\text{introjected})} - 2*\overline{(\text{external})}$$

To ensure that we could use the RAI, we checked a second order factorial structure of the AMS instrument. When considering only the four dimensions of the RAI, whether the measurement model fit was acceptable: χ^2/d.o.f. = 4.659, p < .001, RMSEA = 0.065, SRMR = 0.067, NFI = 0.94, IFI = 0.95, CFI = 0.95, TLI = 0.94. Reliability of each subdimension was good: ω = 0.83, 0.92, 0.81, 0.83.

For the SAES instrument, a second order factorial structure was also confirmed: χ^2/d.o.f. = 3.408, p < .001, RMSEA = 0.053, SRMR = 0.052, NFI = 0.90, IFI = 0.93, CFI = 0.93, TLI = 0.92 and reliability of the overall instrument was good (ω= .87). On such basis, we calculated an engagement index (EI) by averaging all the SAES items.

For the PTAI scale, a confirmatory factor analysis supported the validity of the 4-factor structure of the instrument: χ^2/d.o.f. = 3.872, $p < 10^{-3}$, RMSEA = 0.058, SRMR = 0.055, NFI = 0.95, IFI = 0.96, CFI = 0.96, TLI = 0.95. AVE was greater than the 0.5 threshold for each dimension: 0.57, 0.65, 0.67, 0.64, respectively. Each AVE estimate was also greater than the squared correlation estimates for any two dimensions of the scale (see Supplemental Material). McDonald's ω for each dimension was good: 0.85; 0.91; 0.90; 0.89, respectively. Overall, our analysis confirms convergent and discriminant validity of the instrument.

For the drop-out intention, the reliability of the 4-item scale was acceptable: ω = 0.75. Therefore, we calculated a single drop-out index (DI) by averaging the four items.

Concerning the nonbinary measure of gender, in order to obtain a unique gender identification index, we used a 1-d Rasch analysis. Specifically, after removing the two items about androgyny due to very high frequency of the "not at all" score (> 95%), we coded the remaining four items about femininity and masculinity as follows: the two items about femininity were left unchanged, while we reversed the two masculinity items. Therefore, a score of 0000 corresponds to a student who sees himself as a male, is seen by others as a male, does not see himself as female and is not seen by others as female. Conversely, a score of 6666 corresponds to a student who sees herself as a female, is seen by others as a female, does not see herself as male and is not seen by others as male. Rasch analysis showed that the data fit the model well: person reliability was .84, items separation was 2.75. All items had satisfactory INFIT MNSQ (min = 0.82, max = 1.14) and OUTFIT MNSQ (min = 0.78; max = 1.07). Point-measure correlation of the four items ranged from .93 to .95. Using the calculated Rasch measures in logit as a gender identification index (GII), high positive scores indicate respondents that are more likely to identify themselves in the feminine gender while low negative scores indicate respondents more likely identifying in the masculine gender. More details are reported in the Supplemental Material.

Finally, to address the first research question (RQ1), we first applied a Multiple Correspondence Analysis (MCA) to data collected through the physics identity scale. MCA is a multivariate technique that extends Principal Component Analysis to categorical data, enabling the exploration of patterns of association and opposition among categorical response modalities [69]. MCA achieves this by converting categorical variables into a binary indicator matrix, where each category is represented as a separate binary variable (indicating presence or absence). The analysis then projects these binary variables into a reduced-dimensional space, preserving the relational structure of the original data. The resulting dimensions—also referred to as factors—capture the underlying structure of associations within the dataset. From these dimensions, factorial scores are computed for both individual categories and subjects, facilitating the visualization of data in a lower-dimensional space. This is often accomplished through biplots, which illustrate the relationships among categories and the proximity between individual observations. The interpretation of these dimensions is guided by the associations between category modalities and the directionality (positive or negative) of the factorial scores [70]. In our case, the categorical data were the responses to all the 15 retained items of the SE-PHYS, SI-PHYS, SB-PHYS and PR-PHYS sub-scales of the identity measure. Then, the factorial scores obtained from the MCA were used to perform a hierarchical cluster analysis (HCA) aimed at identifying the latent identity profiles associated with our sample [71]. We used the following criteria to select the optimal number of clusters: i) subsequent subdivision in the dendrogram sequence produces a limited increase of the ratio of the interclass and total variance (called *inertia* in the MCA analysis); ii) subsequent subdivision in the dendrogram sequence produces at least one cluster with less than 5% of cases of the sample. This choice was aimed at avoiding the identification of clusters with low validity and hence harder to interpret. Both criteria allowed us to obtain a description of our sample which was not only detailed in terms of their identity profiles, but also valid from the statistical viewpoint. Specifically, each profile consisted of a specific pattern of the modalities used by individuals in their responses to the items of the identity sub-scales. In such a way, the emerging profiles revealed a unique association of the dimensions of our identity framework. Finally, criterion-related validity evidence for the emerging profiles was collected in two ways: (i) association of the five identity profiles with the PS-PHYS subscale with a 1-way analysis of variance (ANOVA); (ii) capability of the PS-PHYS score to predict membership in each of the five identity profiles, entered into the regression as dummy variables, with subsequent binary logistic regressions. Model fits were evaluated through omnibus χ^2 tests and Cox & Snell and Nagelkerke R Square.

To address our second research question (RQ2), we used multinomial logistic regression to examine the predictive value of profiles' membership of academic motivation, engagement, anxiety, intention to drop-out and gender, as measured by nonbinary scale. Model fit was in this case evaluated using the likelihood ratio χ^2 test, deviance χ^2 tests, and McFadden's pseudo R-square.

To answer the third research questions (RQ3), we performed a linear regression, taking DI as dependent variable and each of the profile membership, entered into the regression as dummy variables, as independent variables. Model fit was evaluated through adjusted R square and F test. We checked collinearity through Variance Inflation Factor (VIF, acceptable values lower than 10) and autocorrelation in the residuals through Durbin-Watson index (acceptable values around 2). Normality of residuals and homoscedasticity were inspected through histogram and dispersion plots.

Both MCA and CA were carried out by means of the package SPAD v. 5.6. All regression analyses and statistical analyses were carried with IBM SPSS and AMOS v.30 package.

V. RESULTS

A. Descriptive statistics of the measured variables

Table 1 shows the correlations between each of the measured variables. All physics identity dimensions are positively and significatively correlated with each other, except for the sense of belonging and self-perception as a physics person. Identity dimensions, as expected, are all positively correlated with engagement and academic motivation. We also note that self-perception, interest and perceived recognition are positively correlated with the Worry dimension of anxiety, which is negatively correlated with Sense of Belonging. All the other anxiety dimensions are negatively correlated with all the identity dimensions. A similar trend was found for the intention to drop out. Finally, we note that the gender identification index is negatively correlated with self-efficacy and perceived recognition, while correlations with the other identity dimensions are not significant.

Descriptive analysis shows that all variables follow a normal distribution except the interest dimension of identity.

Table 1. Descriptive statistics of the measured variables

Variable	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13
1. PS-PHYS	-												
2. SE-PHYS	.25**	-											
3. SI-PHYS	.31**	.27**	-										
4. SB-PHYS	.04	.24**	.10**	-									
5. PR-PHYS	.35**	.34**	.27**	.17**	-								
6. RAI	.18**	.23**	.34**	.26**	.16**	-							
7. EI	.31**	.22**	.45**	.45**	.34**	.47**	-						
8. Worry	.36**	-.04	.19**	-.09**	.11**	.03	.27**	-					
9. Emotionality	.09**	-.26**	.04	-.28**	-.06	-.16**	-.01	.46**	-				
10. Interference	-.07*	-.25**	-.10**	-.35**	-.15**	-.33**	-.25**	.17**	.46**	-			
11. Lack of confidence	-.12**	-.49**	-.17**	-.34**	-.29**	-.27**	-.33**	.17**	.47**	.42**	-		
12. DI	-.12**	-.30**	-.17**	-.35**	-.19**	-.40**	-.34**	.07*	.30**	.36**	.41**	-	
13. GII (logit)	.04	-.25**	.01	-.03	-.09*	-.03	.11**	.14**	.32**	.16**	.21**	.13**	-
Mean	3,77	3,67	4,84	3,30	3,60	11,36	4,36	4,22	3,07	3,03	2,66	2,49	-0.92
SD	0,99	0,77	0,47	0,98	1,10	3,66	0,47	0,77	1,23	1,16	1,04	1,41	3,37
Min	1	1	1	1	1	-9.25	1.48	1	1	1	1	1	-4.85
Max	5	5	5	5	5	18.00	5	5	5	5	5	5	4.68
Asymmetry	-0.741	-0.600	-4.475	-0.311	-0.607	-0.998	-1.404	-1.294	-0.117	-0.064	0,378	0,438	0,354
Kurtosis	0.005	0.212	25.011	-0.555	-0.265	1.606	3.002	1.767	-1.133	-0.992	-0.570	-1.204	-1.162

** p < .01; PS-PHYS: perception of the self as a physics person; SE-PHYS: physics self-efficacy; SI-PHYS: student interest in physics; SB-PHYS: sense of belonging in physics; PR-PHYS: perceived recognition in physics; RAI: relative autonomy index; EI: engagement index; DI: drop-out intention; GII: gender identification index

Table 2. Description of the 5 emerging identity profiles

Profile	Name	Description
1	Enthusiast	These students are confident, passionate, recognized by instructors, and embedded in the peers community.
2	Committed	These students are very interested in physics and feel rather confident but may not yet be fully recognized by instructors or integrated in the peers' community.
3	Isolated	These students lack recognition by instructors and peers' community connection, which can hinder identity development.
4	Neutral	These students have neither weak nor strong interest and are only moderately engaged in the instructors and peers' community
5	Disengaged	These students struggle with confidence and may not see themselves as part of the physics community since they lack both recognition by instructors and peers' relationships.

A. Physics identity profiles

The MCA extracted 52 factorial dimensions. After applying the Benzécri/Greenacre simplified formula of re-evaluation, the first three factorial dimensions account for 86.50% of the total inertia (58.05%, 23.34%, 5.10%, respectively). In consideration of the high number of factorial dimensions extracted, such a percentage of variance can be considered satisfactory. The first factor mainly captures the variation of self-efficacy and perceived recognition from high values (negative polarity) to low values (positive polarity). The second factor captures variations from a moderate perception of self-efficacy (negative polarity) to a low perception of self-efficacy and sense of belonging (positive polarity). The third factor captures variations from a moderate perception of interest and recognition to a high interest and a good perceived recognition and self-efficacy (positive polarity).

The detailed description of the first three factors and the distribution of students in the factor 1 – factor 2 plane are reported in the Supplemental Material. The HCA returned three possible partitions: 3, 5 or 7 clusters. Interclass inertia/total inertia was 0.255, 0.360 and 0.439, respectively. Thus, increasing partitioning from 5 to 7 clusters would not have significantly increased the interclass/total inertia ratio.

Moreover, partitioning in 7 cluster would have produced a cluster with less than 5% of cases (4.7%). Thus, the partition in five clusters was chosen as the optimal cluster analytic solution. Cardinalities of emerging clusters are 164 (19.1%), 328 (38.2%), 69 (8.0%), 245 (28.5%), 53 (6.2%), respectively. In the Supplemental Material, we report a summary of the most significant modalities characterizing the five profiles and the distribution of the clusters plotted in the factor 1 – factor 2 plane.

In Table 2, we provide a brief description of each profile.

Table 3. Results of the logistic regressions for the five identified profiles

	Self-identification score			
Profile	β (SE)	OR	$\Delta\chi^2$	R^2
Enthusiast	0.69 (0.11)***	2.00	46.430***	.055
Committed	0.24 (0.07)***	1.27	10.498**	.009
Isolated	-0.49 (0.12)***	0.61	17.041***	.046
Neutral	-0.33 (0.07)***	0.72	18.752***	.018
Disengaged	-0.49 (0.13)***	0.61	13.596***	.034

* p < .05. ** p < .01. *** p < .001. SE = Standard Error; OR = Odds Ratio

The 1-way ANOVA shows that the five profiles are significantly associated with the PS-PHYS scale: Welch's F = 20.549, d.o.f. = 4; 207.313, p<.001; η^2 = 0.10. Students in the Enthusiast profile have the highest score (4.22 ± 0.07, s.e.), followed by the Committed (3.91 ± 0.05), Neutral (3.54 ± 0.05), Isolated (3.28 ± 0.16) and Disengaged (3.26 ± 0.17). Post-hoc tests show that the Enthusiast and Committed profiles have an identity score significantly different from that of all the other profiles (p<.001).

Moreover, Enthusiast profile has an identity score significantly different from that of the Committed profile (p<.01), while the differences between the Isolated, Neutral and Disengaged profiles are not statistically significant (p = .459, p = .546, p = 1.000, respectively). The binary logistic regression support the evidence that the PS-PHYS scale significantly predicts membership in each of the five profiles. Table 3 reports the regression coefficients, standard error and odds ratios for each of the five tested binary logit models, as well as omnibus chi-square tests of significance with respect to a model with no predictors and McFadden R^2. Figure 1a-e show the estimate plots with confidence intervals for each of the five profiles.

B. Predictors of identity profiles membership

In the multinomial logistic regression, we used as dependent variable the 5-cluster membership, while the four profiles Committed, Isolated, Neutral and Disengaged were subsequently compared to the baseline profile Enthusiast. This choice was due to the fact that this cluster was characterized by students with the highest identification with physics. The likelihood ratio chi-square test was statistically significant, $\chi^2(32)$ = 341.341, p < .001, indicating our model containing the full set of predictors fit the data significantly better than a null (or intercept-only) model. The Deviance chi-square, $\chi^2(3388)$ = 2084.957, p=1.000, test suggests that the model can be considered a good fit to the data. McFadden's pseudo R-square for this model was .14, indicating a moderate improvement in the fit of our full model compared to a model containing no predictors. Next, we tested the omnibus effect of each of the predictors in the model, which allowed us to determine which contributed significantly to the overall model fit.

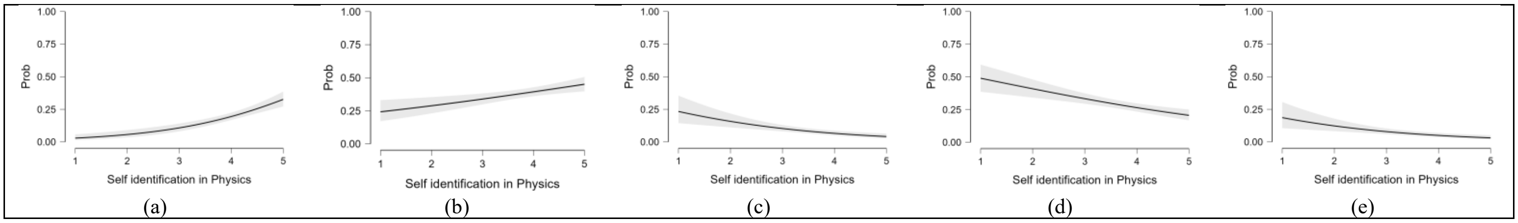

Figure 1. Estimate plot of probability for profile membership: (a) Enthusiast; (b) Committed; (c) Isolated; (d) Neutral; (e) Disengaged

The likelihood ratio tests were statistically significant ($p < .01$) for all predictors except two anxiety dimensions, Worry and Interference, which were eliminated from the model. Table 4 presents the regression coefficients, standard error and odds ratios for each of the four binary logit tested models. First, we note that, for all models, the intercept is significant. For Committed vs. Enthusiast and Neutral vs. Enthusiast models, the intercept is positive, meaning that the likelihood of being associated with Committed and Neutral profiles with respect to the Enthusiast profile is significantly greater than 0, independently of the measured predictors. The opposite holds for the Isolated and Disengaged vs. Enthusiast models.

When we analyze the effect of the measured predictors, for the first model, Committed vs. Enthusiast, only lack of confidence emerged as a significant predictor, holding the remaining effects constant. The positive slope and odds ratio indicate that a student with higher anxiety due to lack of confidence is 1.6 times more likely to be associated with the Committed profile with respect to the Enthusiast profile. For the Isolated vs. Enthusiast profile model, three predictors – EI, emotionality, lack of confidence – are statistically significant. We note that emotionality and lack of confidence have positive slopes, meaning that a student with a higher score in these scales is more likely to be associated with the Isolated profile than Enthusiast profile. For instance, a high score in the lack of confidence scale leads to an increased likelihood of membership in the Isolated profile of 2.7, while a high score in the emotionality scale almost doubles the likelihood of membership in this profile. Differently, lower scores in academic engagement lead to an increase in the likelihood of membership in the Isolated profile with respect to the Enthusiast profile of a factor of almost 3. Also for the Neutral vs. Enthusiast profile model, we found that lower engagement and higher lack of confidence are associated with increased likelihood of being associated to the Neutral profile. However, for this model, we note that a lower motivation and identification in the feminine gender slightly increases the likelihood of membership in this profile. Finally, for the Disengaged profile vs. Enthusiast profile model we found that higher anxiety due to lack of confidence leads to an increasing probability of being associated with the Disengaged profile rather than the Enthusiast profile of a factor of 5. Similarly, higher identification with feminine gender increases the likelihood of being associated with this profile of a factor of about 1.2.

C. Profiles membership as predictors of drop-out intention

The results of the linear regression are shown in Table 5. Note that we took the Enthusiast profile as reference. The final model, $F(4, 854) = 29.810$, $p < .001$, explained about 12% variance in the data ($R^2 = 0.118$). Durbin-Watson index is 1.963, which suggests independence of residuals. VIF values for all independent variables are around or lower than 2, which suggests absence of collinearity among the predictors. The results show that being in the Isolated, Neutral and Disengaged profiles significantly increases the intention to drop-out with respect to being in the Enthusiast profile. Note that being in the Committed profile does not change the likelihood of dropping out. Figure 2a-d shows the estimate plots with confidence intervals for each of the four profiles used as predictors.

Table 4. Results from multinomial logic regression for profile membership – model 1. Reference profile =1

	Profile 2 vs. 1		**Profile 3 vs. 1**		**Profile 4 vs. 1**		**Profile 5 vs. 1**	
	β (SE)	OR	β (SE)	OR	β (SE)	OR	β (SE)	OR
Intercept	1.12 (0.26)***		-2.13 (0.45)***		0.80 (0.27)**		-1.99 (0.46)***	
RAI	-0.19 (0.13)	0.824	0.10 (0.19)	1.105	-0.36 (0.14)*	0.696	-0.23 (0.20)	0.797
EI	0.00 (0.14)	0.992	-1.14 (0.20)***	0.320	-0.33 (0.15)*	0.719	-0.53 (0.21)*	0.586
Emotionality	0.23 (0.12)	1.254	0.67 (0.21)**	1.947	0.02 (0.13)	1.024	-0.095 (0.21)	0.909
Lack of confidence	0.50 (0.14) ***	1.647	1.00 (0.21)***	2.707	1.04 (0.15)***	2.831	1.67 (0.23)***	5.325
GII	0.01 (0.03)	1.014	0.10 (0.05)	1.100	0.08 (0.03)*	1.078	0.20 (0.06)***	1.219

* $p < .05$. ** $p < .01$. *** $p < .001$. SE = Standard Error; OR = Odds Ratio. Profiles: 1: Enthusiast; 2: Committed; 3: Isolated; 4: Neutral; 5: Disengaged. RAI: relative autonomy index; EI: engagement index; GII: gender identification index

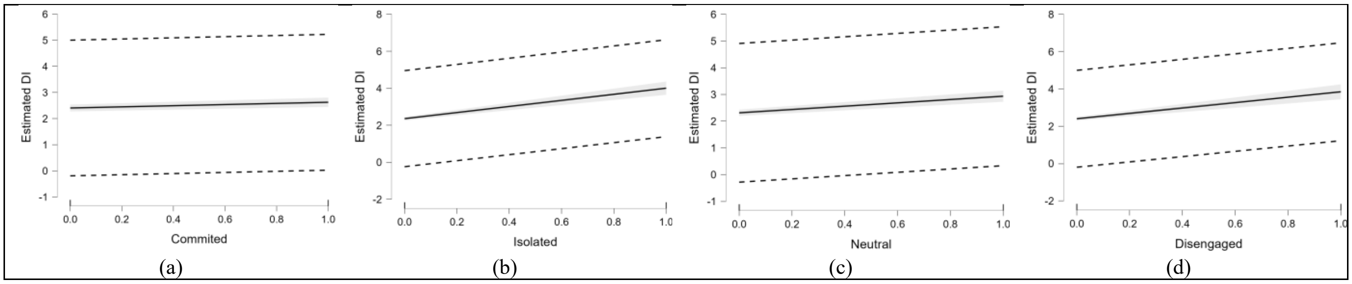

Figure 2. Estimate plots of DI scores for the four profiles Committed (a), Isolated (b), Neutral (c) and Disengaged (d) with respect to the Enthusiast profile

VI. DISCUSSION

This study aimed at investigating physics identity of first-year undergraduate physics students by using a person-centered quantitative approach. Specifically, we examined the number and characteristics of different physics identity profiles, as well as how factors such as gender identification, academic motivation, engagement and anxiety influence profile membership. We also tested whether profile membership was associated with persistence in the degree course. In the following, we discuss our results according to our research questions.

A. RQ1

First of all, the MCA allowed us to uncover latent patterns and associations between the different modalities used by the students in their responses, so that it can be easier to infer for the involved sample which are the primary dimensions that describe physics identity, in our case self-efficacy and recognition. The MCA, in particular, revealed that among the dimensions of the identity framework, students' responses can be primarily summarized by their perceived self-efficacy and recognition, which explain about 60% of the variance in the data. This result adds to current literature in that higher perception of self-efficacy may positively affect the development of identity, while a lower perception may have a negative impact on identity even for those students whose initial preparation in physics could support their retention and increase their performance [5, 12, 48, 72]. Moreover, the MCA also confirmed the relevant role of recognition from instructors in identity development. In other words, if students perceive that their instructors do not see them as being capable of excelling in physics, it can impact on their identity as physicists [10, 23].

Table. 5. Standardized coefficients of the DI score regression

		95% C.I.		
Profile	β	lower	upper	VIF
Committed	0.076	-0.010	0.161	1.854
Isolated	0.318***	0.246	0.390	1.307
Neutral	0.200***	0.116	0.284	1.783
Disengaged	0.247***	0.177	0.317	1.242

*** $p < .001$

Second, findings from the HCA suggest that the diversity of physics identity among first-year undergraduates can be best captured by five profiles: (i) Enthusiast; (ii) Committed; (iii) Isolated; (iv) Neutral; (v) Disengaged. The emergence of these five distinct profiles demonstrates that physics freshmen students are not a homogeneous group from the viewpoint of their physics identity but can instead be categorized into subgroups with unique characteristics related to the four dimensions – self-efficacy, interest, recognition and sense of belonging – included in our physics identity framework. This result confirms previous research carried out about science and engineer identity [62, 73-74], and emphasizes the nuanced and multifaceted nature of disciplinary identity [75].

The most prevalent profile (Committed, 38%) corresponds to a student who is genuinely interested in physics and has a good perception of self-efficacy and recognition. Students associated with this profile are likely to be on the right track and can still further develop their physics identity during their academic trajectory [76]. The second most frequent profile is Neutral (28.5%), which includes students somewhat interested in physics but have no clear perception of their self-efficacy and recognition by instructors. These students may be still "sniffin' around" with a sense of expectation with respect to the degree course, chosen for extrinsic factors as the perceived utility in terms of future careers, as suggested by the result that lower RAI predicts significantly membership in this profile. They can also not be well included in the community as perceived belonging does not play a relevant role for this profile. As we will discuss later, these students may be at risk of not completing their academic path. An interesting finding is that about 20% of the students belong to the Enthusiast profile. These students share high interest and perceived competence, as well sense of belonging and perceived recognition, and are likely to have formed their identity already at the high school, thus confirming findings of previous studies [2, 77]. Finally, a concerning finding is that about 14% of the students are associated with profile 3 (Isolated, 8%) and profile 5 (Disengaged, 6%) characterized by low scores in all identity dimensions, especially perceived self-efficacy and recognition. Students who are more aligned with these profiles are characterized also by low self-identification with physics. As we will discuss later, they may experience exclusion or alienation and may be at a higher risk of dropping out [78].

B. RQ2

The present study provides further evidence that gender significantly influences STEM identity profiles among first-year undergraduates. However, our person-centered approach combined with a non-binary measure of gender identification revealed different patterns within the sample. Specifically, female identified students were more likely to be classified within profiles 4 (Neutral) and 5 (Disengaged) with respect to profile 1 (Enthusiast). Specifically, our result suggests that perceived competence and instructor recognition may be particularly susceptible to gender disparities, in line with previous research [9, 27, 79-80]. The result that students who identify more in the feminine gender are less likely to be associated with profiles 1 (Enthusiast) and 2 (Committed) may be interpreted by hypothesizing that the internalization of physics identity may occur differently for female identified students than for their male counterparts, and that female identified students may develop their disciplinary identity later in their academic careers, as suggested by studies in engineering contexts [74].

However, the multinomial logistic regression suggests that the differences between students in the Enthusiast profile and students in the Neutral profile may be due to higher intrinsic motivation of the former students. This finding suggests that self-identification may enhance autonomy, one of the basic psychological needs underlying intrinsic motivation. Moreover, as the Neutral students are characterized also by average self-efficacy, our result suggests that believing in one's ability to succeed in disciplinary tasks may enhance intrinsic motivation by satisfying the competence need [81].

We also found that lower engagement was a significant predictor of membership of profile 3 (Isolated), 4 (Neutral); and 5 (Disengaged) with respect to profile 1 (Enthusiast). The three former profiles are characterized by weak social relatedness and recognition. This evidence supports the idea that positive interactions with peers and instructors can have a beneficial effect on disciplinary identity. Thus, our results confirm that feeling accepted and valued within a disciplinary community enhances motivation to participate and contribute meaningfully to that community [82].

Concerning anxiety towards physics, we found that higher emotionality and lack of confidence are associated with increasing likelihood of belonging to profile 3 (Isolated), which is characterized by low values of sense of belonging and instructor recognition. This result suggests that anxiety may foster feelings of alienation, namely students who fear making mistakes or being judged often withdraw from classroom interactions, weakening their sense of belonging in the physics community [83]. Moreover, avoidance behaviors and poor performance linked to anxiety reduce opportunities for positive feedback from peers and instructors, lowering perceived recognition [84]. We also found that students with higher scores in the lack of confidence dimension of anxiety were almost 3 times more likely to belong to profile 4 (Neutral) and almost 5 times more likely to belong to profile 5 (Disengaged) than students with lower scores. Such results may be justified by an increased emotional arousal due to lack of confidence, namely students who experience high anxiety perceive themselves as less capable, limiting persistence and achievement [85].

C. RQ3

Consistently with previous results in STEM [86-88], the intention to drop-out was significantly associated with membership in profiles 3-5 (Isolated, Neutral and Disengaged), and the association was stronger for the Isolated and Disengaged profiles, which are characterized by very low values in the sense of belonging and perceived recognition scales. About half of the students in each of these profiles have partially or totally agreed with the statement "Sometimes I think of leaving university", for a total of about 29% of the students in our sample. Taking into account that such a percentage roughly corresponds to actual national drop-out rate between first and second year of the physics degree course, our study suggests that the students that are more likely to drop-out from an academic path in physics are those who do not feel part of the physics community. Moreover, our results shed light also on recent findings according to which students who persisted in the physics course until graduation had higher scores in the identity dimension than those who left [4]. Finally, our results confirm that isolation and lack of recognition can lead to forms of attrition that can lead to dropping out from the physics course [8].

VII. LIMITATIONS

Despite the novel approach adopted in this study to investigate physics identity, several limitations should be acknowledged. First, as it is common with person-centered methodologies, the profiles identified are specific to our convenience sample, which may limit the generalizability of these findings. Data were collected from Italian students attending classes in person during the second semester of their first year, thereby excluding those who had already withdrawn after the first semester or were not attending classes in person. Although efforts were made to mitigate sampling bias by including participants from 15 universities across Italy, the sample may not be representative of Italian physics students. Future research should explore whether similar profiles emerge in different institutional contexts and at various stages of course attendance. Moreover, while the study examined key components of physics identity, such as self-efficacy, interest, recognition and sense of belonging, academic performance data could not be collected for all participants. Consequently, the relationship between the identified profiles and academic outcomes could not be fully explored. We know from previous research that there is a bidirectional relationship between identity and academic achievement, namely, students who report higher levels of identity tend to get better grades, and students who perform better in their exams generally report higher levels of identity at the end of the academic year [13]. Subsequent research should therefore aim to address this gap by examining how these profiles relate to performance at various stages of the academic career. Finally, the five profiles were not uniquely associated with the measure of self-identification with physics. Specifically, the three profiles with lower values in the identity dimensions (Isolated, Neutral and Disengaged) were not statistically different when considering the score on the self-identification scale. This result may reflect either a low power of our study or a scarce discrimination of the self-identification scale for lower scores of the remaining dimensions of the identity framework.

VIII. CONCLUSIONS

This study advances the literature on physics identity by adopting a person-centered approach, which enabled us to identify distinct patterns in how students relate to various identity dimensions. Through this lens, five unique physics identity profiles emerged among first-year university students. The analysis also revealed meaningful associations between physics identity and non-cognitive factors such as engagement, anxiety, and academic motivation. These findings warrant for future research to investigate the developmental trajectories and academic implications of these identity profiles, including their potential impact on performance and persistence throughout students' academic careers. The nuanced distinctions uncovered through this approach underscore the need for more refined tools to assess physics identity. Importantly, the study offers several implications for addressing attrition and promoting persistence in undergraduate physics education. First, the observed gender disparities—particularly in perceived competence and recognition—highlight the urgency of implementing targeted strategies to support female students. Initiatives such as mentorship programs, inclusive pedagogical practices, and the visibility of female role models can help foster these critical identity dimensions. Second, the link between low engagement and identity profiles marked by weak social relatedness and recognition suggests that enhancing peer and instructor interactions may strengthen students' science identity. Active learning environments, collaborative projects, and faculty-student engagement can be meaningful means to cultivate recognition and connection [89]. Third, the association between low-identity profiles and dropout intentions emphasizes the importance of identity-focused interventions. Programs that encourage students to reflect on and develop their disciplinary identity—through personalized feedback, career exploration, and recognition of achievements—could play a vital role in improving retention and reduce drop-out rates [90-91], especially within underrepresented minority students [92].

In conclusion, this study highlights the value of adopting multifaceted, context-sensitive, and identity-informed educational practices in physics. By acknowledging the diverse ways students experience and internalize their physics-related journeys, educators can better support student engagement, persistence, and success in the discipline.

IX. ACKNOWLEDGEMENT

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