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DEVELOPMENT OF PHYSICS IDENTITY RESEARCH IN THE LAST DECADE (2014-2024): A BIBLIOMETRIC ANALYSIS

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Abstract :
Physics identity plays a significant role in shaping individuals' careers and academic engagement in physics. This study aims to analyze the development of research on physics identity over the past decade using bibliometric analysis based on Scopus data. A total of 114 documents were collected, then filtered based on publication year (2014–2024), English language, and article type, resulting in 60 articles for analysis. This study examines publication trends, geographical distribution, and under-researched topics in physics identity. Using VOSviewer and Publish or Perish 8 software, the findings indicate a fluctuating increase in publications, with a predominant focus on gender issues and identity-forming factors such as self-efficacy, recognition, and motivation. However, the research of physics identity concentrated in the United States, highlighting a lack of studies in other regions. Additionally, efforts to address the physics identity crisis are still minimal. This study provides a comprehensive synthesis of the field and highlights the need for further research on alternative strategies to mitigate gender stereotypes and enhance physics identity, particularly in countries with low research contributions.

Keywords: Bibliometric Analysis, Gender, Physics Identity, Research Trends

INTRODUCTION

Physics identity is very important because it plays a role in shaping an individual's future. Physics identity is a motivating factor for students in explaining the importance of physics participation in a career (Godwin et al. 2016; Hazari et al, 2010). Students' physics identity influences students' career decisions and academic goals (Hazari et al, 2010). Identity is very important because it can represent what kind of individual they want to be in the future or present (Gee, 2000). A strong physics identity can indicate persistence in a student's career or course (Carlone & Johnson, 2007). Students' physics identity can be a reference in predicting student engagement in physics classes and choosing a career related to physics (Hazari et al, 2010; Cheng et al. 20018). Physics identity can play a major role in students' academics and future career choices (Hazari et al., 2013, Lock et al., 2019, Danielsson, 2012, Gonsalves, 2018). Science identity has been positioned as a key driver of student engagement, career intentions, and professional choices across many disciplines (Hurtado et al, 2009). Physics identity plays a critical role in the physics learning environment.

Studies on physics identity have developed from year to year. Research on physics identity over the past decade has mostly focused on gender issues. Physics is labeled as a masculine discipline (Archer, 2017). Social support from the community actually encourages male students to have a superior physics identity compared to female students (Kalender et al, 2019). In addition, laboratory-based activities can support gender stereotypes where women are only burdened with the task of being secretaries (Doucette et al, 2020). Research related to physics identity then encourages problem solving in the form of the role of learning assistants carried out by students (Close et al, 2016). Physics identity is then associated with other variables such as recognition (Hazari, 2018), self-efficacy (Li, Y. 2024; Bottomley, 2024), interest (Hyater-Adams, 2019; Ulu, 2024), and motivation (Bøe, 2023; Yang et al., 2023). Physics identity in recent years has certainly been familiar in the physics environment.

Research related to physics identity has been quite extensive. The focus of this research generally includes gender issues (Li & Singh, 2022; Randolph et al., 2022; Wulff et al., 2018). Physics identity in men tends to be stronger than in women (Kalender et al., 2019). Gender inequality in the development of physics identity needs to be strengthened, especially for women (Lock & Hazari, 2016). Male students have a better physics identity compared to female students (Bottomley et al., 2024). This gap is caused by several factors, such as social factors (Hyater-Adams et al., 2018) and lack of recognition from those around them (Nokes-Malach et al., 2019). Although previous research has addressed physics identity in the context of gender (Li & Singh, 2022; Randolph et al., 2022), little research has explored effective educational intervention strategies to strengthen physics identity across sociocultural groups. On the other hand, physics identity is still influenced by factors beyond gender such as career understandings that influence recognition and competence in physics identity (Rosenberg, 2024; Whitcomb, 2023). Furthermore, the distribution of research on physics identity is uneven globally, with most research centered in the United States (Hazari, 2018), leaving little research addressing conditions in other countries.

This study aims to provide a comprehensive synthesis of the development of physics identity globally. Publication trends are quantitatively identified by looking at researcher collaborations and popular themes in physics identity research during 2014-2024 using Scopus-based bibliometric analysis. Practically, the findings of this study can be used to design more effective physics education intervention programs that not only increase student engagement but also help shape a strong physics identity among students from various backgrounds. Thus, this study provides a systematic mapping of the development of physics identity studies and provides recommendations for future research. Some of the research questions that will be answered are: (1) How has research on physical identity progressed over the last decade? (2) How is the distribution of research on the physics identity of each country? (3) What are some topics that are still rarely researched regarding physics identity as a reference for further research? Bibliometric analysis assisted by VOSviewer software was used to answer these questions.

RESEARCH METHOD

This study is a descriptive study in the form of a literature review using the bibliometric analysis method (Merigó & Yang, 2017; van Nunen et al., 2018). The bibliometric analysis method applied in this study refers to the approach used in previous studies involving five steps, namely: 1) study design; 2) data collection; 3) data analysis; 4) data visualization; and 5) interpretation of the analysis (Misbah et al., 2024; Haryandi et al., 2024; Rukmana et al., 2023; Misbah et al., 2022) which are presented in Figure 1.

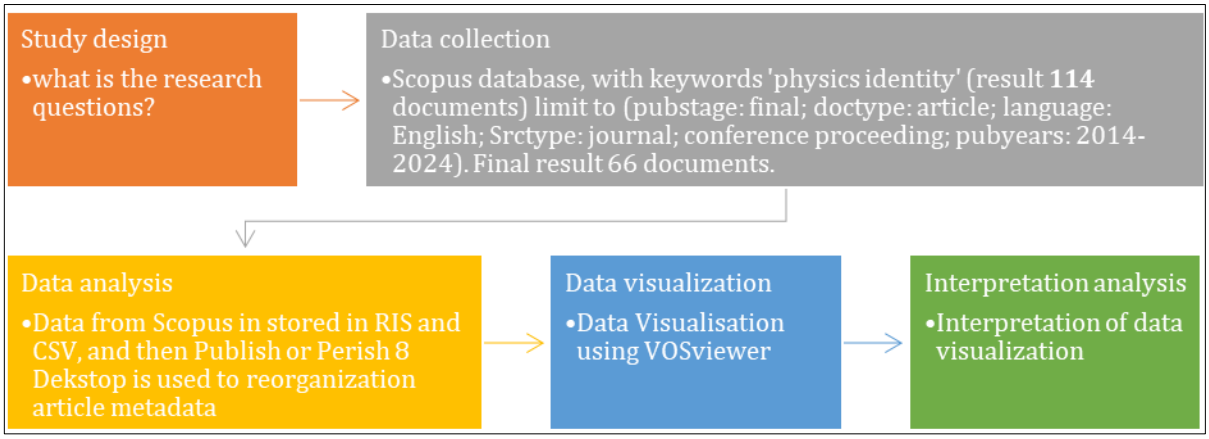

Figure 1. Stages of Bibliometric Analysis

Bibliometric analysis can be seen in Figure 1 which includes 5 stages. The research design refers to the research questions. The research questions include: 1) How has research on physics identity developed over the past decade? 2) How is the distribution of research on physics identity from each country? 3) What are the topics that are still rarely researched on physics identity as a reference for further research?

The data collection stage was carried out through the Scopus database with the keyword "physics identity" in the period 2014-2024. The research was limited to publications in the form of articles, conference papers, articles must be open access, and use English, so that 66 publications were obtained. The data analysis stage was carried out by saving the research that had been obtained in .RIS and .CSV formats. The data was processed using Publish or Perish 8 software to obtain data with the most citations and VOSviewer software to obtain research updates on physics identity and related co-occurrence keywords (Haryandi et al, 2024). VOSviewer software allows data to be divided into network mapping so that the relationship between keywords related to physics identity can be observed (Zakiyyah et al., 2022). After the data is visualized through VOSviewer mapping, the data is then interpreted so that physics identity research updates can be obtained.

RESULTS AND DISCUSSION

Publications per Year Related to Physics Identity in 2014-2024

The following is the number of publications related to physics identity during 2014-2024 which is shown in Figure 2.

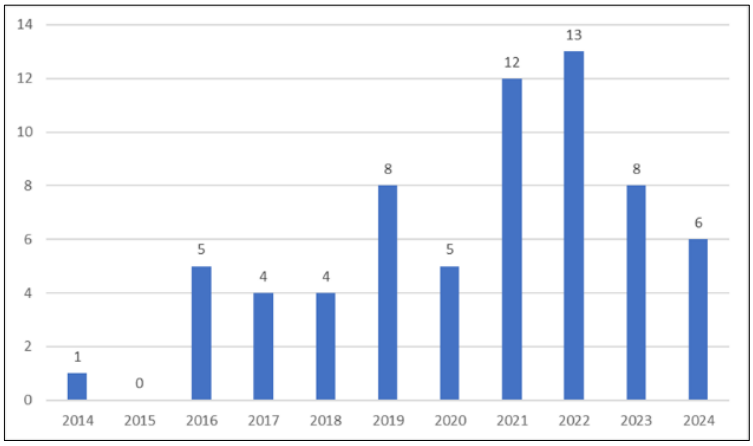

Figure 2. Number of Physics Identity Publications per Year Over the Last Decade

Figure 2 indicates that the largest number of physics identity publications was in 2022. The number of research publications related to physics identity during the past year has decreased from the previous year. Predictions for 2025 cannot be predicted considering the number of publications from

year to year has increased and decreased. Physics identity is expected to be reviewed to increase the scope of physics research, especially in the field of education because the physics environment (education) has a major influence on the performance of physicists (Hazari, 2018). Physics identity research can be developed in the future.

Furthermore, further analysis was conducted to determine the distribution of publications related to physics identity in each country, which is presented in Figure 3.

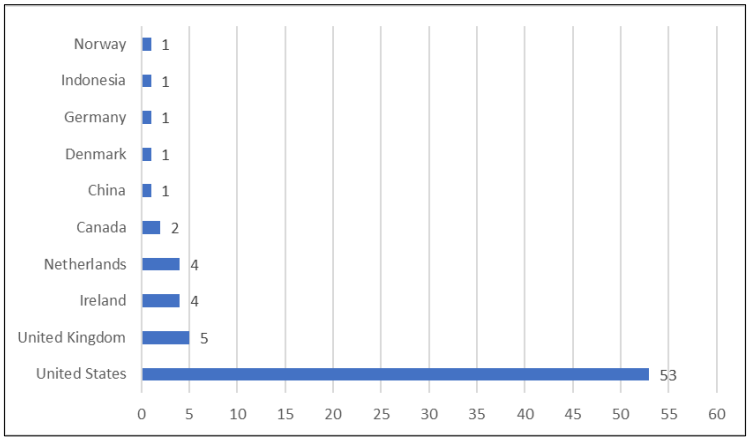

Figure 3. Distribution of Publications from Each Country

Figure 3 shows that the topic of physics identity in physics education research is still rarely studied outside the United States. The number of published articles finds a very large gap. Therefore, research on physics identity needs to be conducted in countries other than the US, especially China, Denmark, Germany, Indonesia, and Norway. Awareness of the importance of physics identity is still weak in most countries.

The Top Ten Authors Ranked by Citation Count on the Topic of Physics Identity

The following is data for the top ten authors ranked by the number of citations on the topic of physics identity, which is shown in Table 1.

Table 1. Top 10 Authors by Number of Citations

Author	Findings	Cited by	Journal (Quartile)
Archer et al. (2017)	Women involved in physics are called extraordinary women by some. Physics is still considered a "masculine" field.	97	American Educational Research Journal (Q1)
Kalender et al. (2019)	Factors such as personal interest in physics, social support, and self-confidence play an important role in the formation of physics identity. However, males tend to have more self-confidence and social support than females, leading to a stronger physics identity in males.	95	Physical Review Physics Education Research (Q1)
Close et al. (2016)	The role of Learning Assistant helps students develop an integrated physics identity through increased self-confidence, deeper understanding of physics concepts, and opportunities to interact with the physics community.	89	Physical Review Physics Education Research (Q1)
Kalender et al. (2019)	Female students are still reluctant to recognize themselves as part of the physics community because people around them do not recognize them. The motivation of students to be part of physics is weakened by the lack of recognition from the physics community.	80	Physical Review Physics Education Research (Q1)

Author	Findings	Cited by	Journal (Quartile)
Hyater-Adams et al. (2018)	Social dynamics and racially based experiences influence physics identity beyond cognitive ones. Lack of representation and support in academic environments are additional challenges faced by students from racially minority groups.	78	Physical Review Physics Education Research (Q1)
Doucette et al. (2020)	Laboratory activities have been shown to support gender stereotypes where women are given "secretary" tasks and men are given "technical" tasks. This also affects women's self-confidence and narrows opportunities to develop physics skills.	67	European Journal of Physics (Q2)
Li & Singh (2021)	Motivation and learning outcomes of female physics are still lacking compared to males. This is influenced by less positive perceptions of females. In addition, females are also found to have low self-confidence, making it difficult to maximize performance. Interest in physics is related to gender stereotypes and social expectations that influence participation in physics.	47	Physical Review Physics Education Research (Q1)
Wang & Hazari (2018)	Students' physics identity at the secondary level is influenced by appreciation, open praise, and recognition in everyday interactions. Such recognition increases students' self-confidence and engagement, especially for girls and minority groups. In this way, participants can develop positive relationships with the physics community.	45	Physical Review Physics Education Research (Q1)
Hyater-Adams et al. (2019)	Self-confidence, interests, racial stereotypes, and representations of physics influence students' physics identity. Social factors such as discrimination and marginalization hinder the formation of a good physics identity.	44	Physical Review Physics Education Research (Q1)
Lock & Hazari (2016)	The development of a stronger physics identity, especially for women, can be achieved by discussing gender inequality in physics. Such discussions promote awareness of the challenges that must be faced and support the creation of a positive environment in the field of physics.	43	Physical Review Physics Education Research (Q1)

Table 1 shows the ranking of the 10 authors who have produced publications with the highest number of citations. The highest number of citations was obtained in 2017, where in the following years there was a spike in quite a lot of physics identity publications. The research is related to gender so that in the following years there were also many research on physics identity related to gender. On the other hand, research on physics identity has begun to show a broad scope. Further research discusses aspects that influence physics identity such as self-efficacy, recognition, motivation, and physics interest. Basically, the findings The research findings encourage structural changes in the physics education environment because the physics identity of individuals, especially women, is still weak.

Top Ten Latest Publications on the Topic of Physics Identity

The following is data for the top ten publications on the topic of physics identity ranked by year of most recent publication, which are shown in Table 2.

Table 2. Ten Recent Publication on The Topic of Physics Identity

No.	Author	Findings	Cited by	Journal (Quartile)
1.	McDermott et al. (2024)	The need for anti-ableism support in education to build a sense of connectedness for neurodivergent individuals in the physics community.	2	Physical Review Physics Education Research (Q1)

No.	Author	Findings	Cited by	Journal (Quartile)
2.	Bottomley et al. (2024)	Female students still have lower physics identity and self-efficacy compared to male students. This can affect their connectedness to the physics community and impact their well-being.	2	International Journal of Science and Mathematics Education (Q1)
3.	Li & Singh (2024)	Recognition is positioned as a predictor for self-efficacy and physics interest. Additional experiments are needed to differentiate causal models and provide information on physics identity in science education.	2	Physical Review Physics Education Research (Q1)
4.	Rosenberg et al. (2024)	Mentorship alternatives can help students to increase their participation in the physics community as well as support in forming a physics identity. In addition, there are indications that career understanding has an impact on recognition and competence in physics identity.	0	Physical Review Physics Education Research (Q1)
5.	Ulu & Yerdelen-Damar (2024)	Metacognition and epistemic cognition influence physics identity through self-efficacy. Social recognition and interest also influence physics identity. Men still have a higher tendency than women in all four aspects.	0	Physical Review Physics Education Research (Q1)
6.	Gertz et al. (2024)	Social norms and expectations still marginalize female students in high school in physics learning. Many students consider physics less meaningful and the formation of a physics identity is successfully formed by few students.	0	International Journal of Science and Mathematics Education (Q1)
7.	Whitcomb et al. (2023)	Physics students have a higher identity than non-physics students towards physics identity. Students' physics identity decreases in the fourth year when many students begin to consider changing fields. Recognition is the best predictor of physics identity and recognition and affirmation can be done to support the development of students' physics identity.	8	Research in Science Education Journal (Q1)
8.	Bottomley et al. (2023)	Gender differences still affect physics identity, self-efficacy, and recognition received by students. Male students tend to have higher academic grades than female students. Female students report that less recognition affects connectedness and involvement in the physics community.	4	European Journal of Physics (Q2)
9.	Boe (2023)	Students tend to adjust their behavior from environmental recognition. High achieving students have a competitive tendency to maintain environmental recognition or can be called maintaining their physics identity.	2	Physics Education Journal (Q2)
10.	Gonsalves et al. (2023)	challenges and decisions in pursuing physics, using metaphors such as the “river of life” to illustrate the trajectory of their experiences in physics. These findings highlight the importance of cross-cultural perspectives and the use of stories to understand the diverse identity journeys of physicists.	1	Physical Review Physics Education Research (Q1)

Table 2 shows the findings of 10 recent publications on the topic of physics identity. It seems that gender issues have not been addressed for several years. Awareness of physics identity needs to be supported by various parties from various circles so that it is difficult to really get a strong identity score. Apart from gender, a study needs to be conducted for social influences both at home and at school in the formation of physics identity as shown by Boe (2023). Solutions to the physics identity crisis also need to be studied as research has been conducted by Rosenberg (2024). Alternative solutions to the problem seem to be still little developed in dealing with the weakness of a person's physics identity.

Visualization of Research Trends in Physics Identity

VOSviewer is able to present bibliometric analysis mapping with three types of visualization, one of which is the network visualization shown in Figure 4. There are 89 recognizable items, divided into 10 clusters with different colors, namely red, green, blue, yellow, purple, turquoise, orange, brown, pink, and creme.

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The visualization in Figure 4 is obtained from VOSviewer according to keywords from research publications over the past 10 years. 89 keyword co-occurrence items were obtained and classified into 10 clusters. Each cluster has a different color as presented in Figure 4. These clusters show the development of research related to Physics Identity in Physics Education. The clusters in question can be seen in more detail in Table 3.

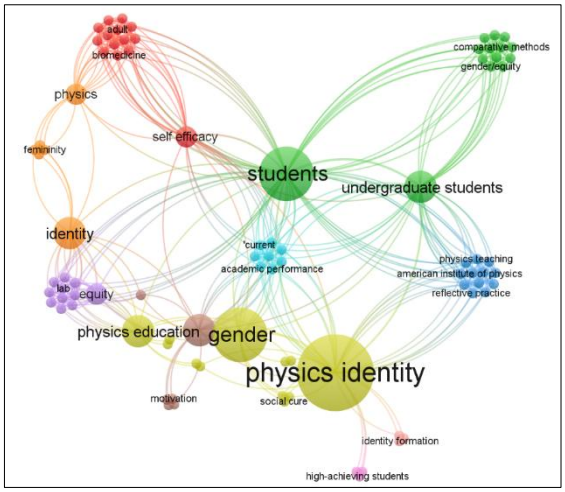


Figure 4. Keywords Related to Physics Identity

Table 3. Keywords Detail of Each Color Cluster

No.	Cluster Color	Number of Items	Keywords
1.	Red	14	Adult, article, biomedicine, female, human, humans, male, molecular recognition, peer group, self concept, self efficacy, stereotypy, student, teaching assistant
2.	Green	14	Comparative methods, education, feminism, gender stereotypes, gender/equity, multiple identities, multiple-case study, organizational policies, professional levels, research, social communities, students, undergraduate students, women's issues
3.	Blue	12	American institute of physics, curricula, hands-on experiences, national academies press, nnational research council, physics teaching, qualitative case studies, reflective practice, reflective practices, scaffolds, surveys, teaching

No.	Cluster Color	Number of Items	Keywords
4.	Yellow	12	Belonging, case study, gender, life-history, multiple representations, physics education, physics identity, physics teacher education, social cure, transition, upper secondary school, wellbeing
5.	Purple	11	Equity, ethnographic observation, experiment and analysis, gender differences, gender-differences, growth trajectories, lab, laboratories, labs, stunted growth, task division
6.	Turquoise blue	8	'current, academic performance, biographies, perceived recognition as a physicist, physics identity, recent researches, undergraduate degrees
7.	Orange	6	Femininity, identity, judith butler, physics, science, stem
8.	Chocolate	6	Motivation, perceived recognition, science identity, self-efficacy, social belonging, structural equation modeling
9.	Pink	3	High-archiving students, recognition, secondary physics
10.	Creme	3	Identity formation, negative and positive perceptions, physics and participation

The discussion is focused on connecting data and analysis results with the problem or research objectives and the wider theoretical context. Could this discussion be the answer to the question why these facts were found in the data?

A deeper analysis was conducted to see the relevance of keywords to the topic of physics identity. The results of the analysis in the form of Vosviewer output display can be seen in Figure 5.

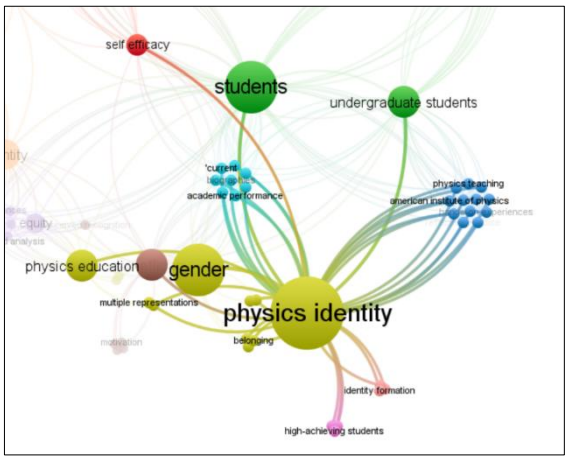


Figure 5. Keywords Directly Related to Physics Identity

Figure 5 shows that physics identity is located in the yellow cluster. A person's interest in physics and desire to be part of the physics world are closely related to the formation of physics identity (Bottomley et al., 2021; Gertz et al., 2024). In research on physics identity, the topic of gender is quite prominent. Gender issues are still a barrier for women to get involved in physics (Rosenberg et al., 2024; Yang et al., 2023). In addition, diverse representation plays a role in shaping physics identity (Munfaridah et al., 2022). Physics identity is also significantly influenced by the role of physics teachers or educators (Mathis & Robertson, 2021; Potvin & Hazari, 2016).

Physics identity is also related to the red cluster, which illustrates the importance of self-efficacy. High levels of self-efficacy can encourage individuals to become part of physics (Ulu & Yerdelen-Damar, 2024; Whitcomb et al., 2023). Research on physics identity has included various groups, including adults (Gonsalves et al., 2023), males (Stoeckel & Roehrig, 2021), females (Cwik & Singh, 2022; Randolph et al., 2021), students (Maries et al., 2021; Prefontaine & Hinko, 2019; Rethman et al., 2021), and physics teaching assistants (Cwik & Singh, 2022; Kalender et al., 2019; Li & Singh,

2022). The green cluster shows a strong relationship with physics identity, especially in studies focusing on physics students and undergraduates (Prefontaine et al., 2021). Many studies on physics identity have discussed gender stereotypes (Heeg & Avraamidou, 2021; Li & Singh, 2021), feminism (Moshfeghyeganeh & Hazari, 2021), and women's issues (Archer et al., 2017; Potvin & Hazari, 2016). This is due to the limited number of female scientists in the early development of physics (Rosenberg et al., 2024).

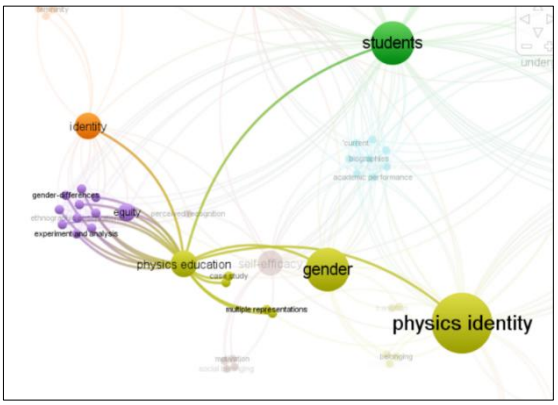
Physics identity is also related to the blue cluster, which illustrates how direct experiences shape physics identity (Gonsalves et al., 2023). The curriculum in physics education also influences the formation of physics identity (Lock, Dusen, et al., 2019; Rethman et al., 2021), and the scaffolding approach in physics teaching plays a role in shaping this physics identity (Stiles-Clarke & MacLeod, 2018; Wang & Hazari, 2018). Research on physics identity also includes aspects of equality, especially related to gender (Doucette et al., 2020; Li & Singh, 2024), as well as studies on specific cultures or ethnicities (Doucette et al., 2020; Hazari et al., 2022; Morley et al., 2023). In addition, the use of laboratories in physics education has also been part of physics identity research (Stiles-Clarke & MacLeod, 2018). This relationship is seen in the purple cluster.

Research on physics identity has also included pre-graduate students (Bottomley, 2023), with a focus on the growing importance of physics identity in recent years (Whitcomb, 2023). The influence of physics identity on academic performance has also been studied (Bottomley, 2023), which is reflected in the turquoise cluster. Physics identity is seen as part of scientific identity (Doucette et al., 2020; Hazari et al., 2022), where identity is not something inherent to the individual, but is a result of social formation (Rosenberg et al., 2024). The STEM approach has shown a significant influence in the formation of physics identity (Mcdermott et al., 2024), which is influenced by the orange cluster.

Meanwhile, physics identity has little relationship with the brown cluster, which identifies several indicators that can be used to assess physics identity, such as motivation (Bøe, 2023; Yang et al., 2023), recognition (Li & Singh, 2023; Stump & Holmes, 2022), and self-efficacy. Several other factors that influence physics identity are modeling and the individual's social or environmental background (Avraamidou, 2022; Lock, Hazari, et al., 2019).

The pink cluster focuses more on physics identities associated with high-achieving students (Bøe, 2023; Gertz et al., 2024), as well as individuals who have studied advanced physics (Bøe, 2023). Research has been conducted that has examined physics identity in depth, as reflected in the creme cluster. The urgency of physics identity, especially as it relates to gender, encourages further research on the formation of this identity (Gudyanga & Kurup, 2017). Recent research has also highlighted how positive and negative perspectives influence the formation of physics identity (McDermott et al., 2024; Starita et al., 2020).

Physics education can be grouped into four clusters, as depicted in Figure 6.



Firgure 6. Keywords Related to Physics Education

Figure 6 shows keywords that are highly relevant and closely related to physics identity in the field of physics education. The relationship between physics education and physics identity shows a significant influence on the formation of physics identity itself (Li & Singh, 2024; McDermott et al., 2024). In addition, physics education is also closely related to the formation of identity more broadly

(Hazari et al., 2022; Young, 2022). Research on physics education, reflected through the color purple, covers various aspects, from equality to application in the laboratory (Doucette et al., 2020; Stiles-Clarke & MacLeod, 2018). However, alternatives to improve physics identity through curriculum, learning approaches, and media and strategies used in physics education are still limited to research.

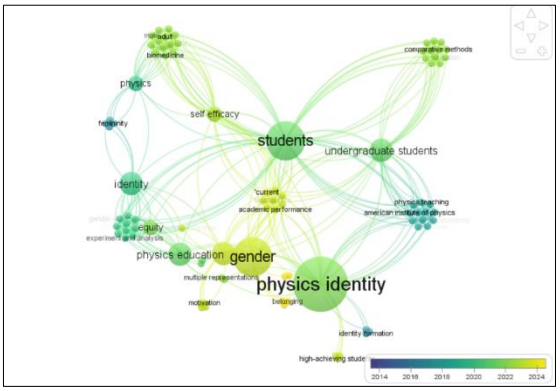


Figure 7. Physics Identity Overlay Visualization Results

VOS Viewer can present bibliometric analysis mapping through three different types of visualizations, one of which is the overlay visualization shown in Figure 7.

The visualization results of the physics identity topic mapping for the past 10 years can be seen in Figure 7. The physics identity research trend that is still often studied is the issue of gender. Although there have been many studies on the relationship between physics identity and gender, it seems that this problem cannot be eliminated. Physics identity is expected to be a topic that needs to be reviewed again to expand physics education research in the following years. Research that links ethnicity, curriculum, and the influence of the learning environment seems to be an interesting topic to improve students' physics identity.

CONCLUSION

Over the past ten years, research on physics identity has experienced ups and downs and a decline in the past year. Research related to physics identity is still too focused on the US and experiences gaps with other countries. Countries outside the US are expected to be able to keep up with the development of physics identity considering that identity needs to be formed to prosper individuals in the physics community. The topics that have been studied mostly find cases of gender stereotypes that affect physics identity and then have an impact on their performance. Topics that have not been widely studied include alternative solutions to the physics identity crisis that interferes with the physics community's development. One of the alternatives that has been found is the demand for students to participate as laboratory assistants or teachers.

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