



Research Trends of Physics Identity Development in University: How About Indonesia?

Putri Dwi Sundari^{1*}, Hidayati¹

¹Department of Physics, Faculty of Natural Sciences and Mathematics, Universitas Negeri Padang, Indonesia.

Received: March 31, 2023

Revised: April 18, 2023

Accepted: June 25, 2023

Published: June 30, 2023

Corresponding Author:

Putri Dwi Sundari

putridwisundari@fmipa.unp.ac.id

DOI: [10.29303/jppipa.v9i6.4087](https://doi.org/10.29303/jppipa.v9i6.4087)

© 2023 The Authors. This open access article is distributed under a (CC-BY License)



Abstract: The concept of physics identity plays an essential role for physics teacher professionalism. That is why physics identity development has become a trend of research in West country. Through this study, we aimed to analyze research related to physics identity development in various international journals. We reviewed 17 empirical studies published in 2013-2023 in reputable journals in context of undergraduate physics. The findings of the study were discussed based on in what ways student's physics identity development, and what factor that influences the development. We identify gaps in the existing knowledge base, particularly in Indonesia context, and we purpose further study directions. This study provides an overview of how physics identity development in university and give information where is Indonesia position.

Keywords: Physics identity; Research trends; Review study

Introduction

Over the last few decades, study on physics identity has been expanded widely in Western country (Gonsalves et al., 2022; Gudyanga, 2017; Lock et al., 2013; Moshfeghyeganeh & Hazari, 2021; Stiles-Clarke & MacLeod, 2016). The studies have become a topic of interest since the researchers and educators in physics education realize that the importance of addressing physics identity of student (Irving & Sayre, 2015). Growing interest in studying physics identity was due to an increasing recognition to the significant findings.

Physics identity related to how individuals identify themselves in physics context (Trujillo & Tanner, 2014). Its importance to understanding how student's belief to their own capabilities that influence to their motivation which impact in promoting inclusion, diversity, and equity in the field (Li & Singh, 2022). Physics identity is an essential context in higher education. The development of physics identity on college students had significant impact to their motivation, engagement, and achievements (Bøe, 2023; Lock et al., 2019). However, there are several factors that influence the development

of physics identity in university. University is the initial stage for students to determine their further career.

Physics is a complicated and basic scientific field that aims to explain the natural world's underlying rules and events. However, many students see it as a difficult and challenging subject (Veloo et al., 2015). Negative perceptions of physics as difficult, abstract, or only suitable for a selected group might lead to students having a low physics identity or even feeling excluded from the discipline (Fisher et al., 2022).

Several prior studies showed that students who has a strong physics identity are more likely to actively participate in physics learning, persevere of challenges, and pursue further career in physics (Bøe, 2023). However, student with weak physics identity tend to have less motivation, have lower self-efficacy and confidence, and are more inclined to disengage from physics-related activities (Fisher et al., 2022). This situation might be different based on gender, ethnicity, and race (Avraamidou, 2020). Therefore, the study about physics identity development needs to be explore in depth because of complexity of identity formation.

How to Cite:

Sundari, P. D., & Hidayati. (2023). Research Trends of Physics Identity Development in University: How About Indonesia? *Jurnal Penelitian Pendidikan IPA*, 9(6), 95-103. <https://doi.org/10.29303/jppipa.v9i6.4087>

Understanding how and what factors that influence the development of physics identity on students is pivotal for physics educators and researchers. In addition, it is also important for teacher preparation program to analyse how college student in physics education develop their identity as future teacher (Purwaningsih et al., 2020). By synthesizing the existing literatures, we could gather broaden knowledge and identify gap.

This study aims to provide a comprehensive synthesis of research on the development of physics identities around the world, and determine Indonesia's position. Indonesia is a multi-cultural and socioeconomic country that offer unique setting for investigating the complex interaction of individual, social, and pedagogical aspects that establish students' physics identities. This study aims to offer insight on the problems and possibilities experienced by Indonesian students on their path to developing a strong physics identity.

Method

Identifying journal articles was the first stage of review study. Identification started by looking for articles in database online using term "physics identity" and "physics identity development". Harzhing's publish and perish with Scopus search engine was used as a tool to search articles. As a result, we identified publications with various type, including journal article, book chapter, conference proceeding, review paper, and letter. Afterwards, we selected only articles published in scientific journal.

Articles were selected using following criteria: (1) article was published around 2013-2023; (2) article was focused on physics identity development in the university; and (3) article was published in reputable journal that provided by <https://www.scimagojr.com/>. Consequently, around 17 articles were selected to be review as shown in Figure 1.



Figure 1. The process of selection the manuscripts

We recognize that article selection process has limitation. First, we only selected article that published in Scopus database, it is likely that we missed out an important contribution that are excluded in this database. Second, this study only focused on articles that published in ten years ago, but did not mean to exclude

valuable studies before 2013. Last, the study only focused on studies done at university level, and due that fails to give broaden knowledge that cut across education level.

Result and Discussion

About 24 manuscripts were analysed to answer this question: *What do we know about physics identity development in higher education?* The papers were analysed based on the following criteria: (1) purpose of the study, research questions, sample studied; (2) method used; (3) how physics identity was developed; and (4) findings. The result of the analysis is presented under the main themes which is in the form of questions as shows in Table 1.

Table 1. Themes of Reviewed Manuscripts

Themes	Literature
<i>In what ways do students construct their physics identity?</i>	Purwaningsih et al., 2020
	Close et al., 2016
	Fracchiolla et al., 2020
	Prefontaine et al., 2021
	Randolph et al., 2022
	Lock et al., 2019
	Hazari et al., 2022
	Gonsalves et al., 2022
	Wulff et al., 2018
	Stump et al., 2023
<i>What factors does influence the development of student physics identity?</i>	Munfaridah et al., 2022
	Wang et al., 2022
	Hazari et al., 2020
	Bøe, 2023
	Bottomley et al., 2023
	Hazari et al., 2010
	Hazari et al., 2017

In what ways do students construct their physics identity?

Purwaningsih et al. (2020) used case study method to explore physics identity and physics teacher identity development of physics-student teacher. The study conducted in one public university in Indonesia with a fourth-year student-teacher named Syahrul. Syahrul carried out an internship program at one of the high schools in Malang for 6 weeks. In exploring Syahrul's identity, the researchers conducted four forms of interview. The reserachers asked Syahrul four questions as follows: (1) belief and perception in teaching and learning physics, (2) past experiences in physics learning, (3) activity in doing internship program, and (4) feeling after finished internship program. All Syahrul's activities when doing internship program was documented and observed using field notes and observation sheets, respectively. From the data obtained, the construction of Syahrul's identity included four compenents, namely discourse identity (implementing

inquiry learning with rhetoric skills), affinity identity (positive relation with peers, teachers, and lecturers), nature identity (positive experiences in high school), and institution identity (positive effects as being member of campus organization). However, this study only involved one participant which mean the findings cannot be generalized, as well as the instruments used need to improve.

If Syahrul constructs identity through his experiences when doing internship program, a study carried out by Close et al. (2016) provide information about the impact of physics learning assistant (LA) program at Texas State University in constructing physics identity. Around 61 LAs who participate in Spring 2014 and Fall 2024 involved in this study. Teaching reflections, program applications, and interviews were used to collect the data. The LA program at Texas State was a core faculty program that emphasized the importance of community and mutual assistance among physics students and faculty. Texas State LA program gives valuable experiences for partisipants in teaching and learning physics, as well as being recognize by both students and faculty as a physics person, and develop competences both in physics and in teaching. The findings of the study showed that LA program support LAs' development of integrated physics identity and let them to be more productive and enjoy the processes of becoming physics people.

Another similar program that used to support physics identity development was informal physics program. This study conducted by Fracchiolla et al. (2020) that seek to look at informal physics programs as sites to explore an individual's physics identity. Two physics graduate students (named Mike and Cecilia) involved in this study and adapted Community of Practice (CoP) framework and narrative inquiry as method. By using semi-structured interview, Fracchiolla and friends used several questions to obtain information about the reasons in involving informal physics program, what they have learned, what they plan next, and what motivation they have in choosing physics. From this study, we know that CoP framework benefited for Mike and Cecilia's membership in informal physics program. They involved in this informal program to encourage children keen on physics. Furthermore, negotiated experiences are the most essential method for both students in identity construction.

The study carried out by Prefontaine et al., (2021) was continuation of Fracchiolla et al. (2020) study. In this study, they continue to explore the impact of informal physics program to physics identity development. However, the participant involved was a leader of the

program (role as facilitators). Adapting CoP framework and dimension of community, a case study was conducted to gain an in-depth and contextualized knowledge of the experiences of facilitators in three distinct informal physics programs. The result showed that by involving in informal physics program, the facilitators have opportunities to develop positive physics identity. In addition, they feel more engage with physics and recognize as a member of physics community. The department or faculty in the university might be able to utilize these findings to create changes that promote more positive identity development for all their physics students.

Another study carried out by Randolph et al. (2022) also about informal physics program. They explore five informal physics program that run by the Department of Physics and Astronomy at Texas A&M University on female students. Semi-structured interviews were conducted to ten female students who facilitate the programs. Students self-reported the effects of their involvement in the programs on their physics identity, values, skills, and viewpoints. Focus on physics identity development, the result showed that students feel more confidence with their competence in physics. They also coveyed both internal and external recognitions. As a facilitator of the programs, they increased their performance in physics. They became accustomed to discussing physics concepts in public, and demonstrating various physics experiments. In addition, the improvement of communication skills while facilitating this program makes it easier to get a job after graduating from university. More importantly, they felt they were experts in physics.

Lock et al. (2019) explored the impact of out-of-class activities to physics identity development and physics careers intention on college student. Around 6772 students from national colleges and universities in Fall 2011 in the USA involved in this study. The study performed structural equation modeling (SEM) to determine the relationship between physics identity dimensions and physics career choice of students who joined out-of-class science and engineering (OCSE). The data obtained using questionnaires. The findings showed that OCSE activities have the greatest impact on performance/competence of students. Even though OCSE activities do not really affect the dimensions of physics identity development, these activities increase physics career intentions. By taking OCSE students experience the largest impact on their recognition beliefs, and this influences the development of a physics identity. The benefit of emphasizing recognition beliefs in OCSE activities may be correlated with enhancing possibilities for students to acquire agency with physics and get interested in physics career fields. The study

solely looks at the influence of OCSE activities on college students' physics identity and career choices, and it may not be applicable to other STEM field or students at different levels of education.

The impact of informal science experiences (ISE) to physics identity development were examined by Hazari et al. (2022). ISE refer to a set of informal STEM learning activities that students involved during the K-4 to K-12. A total of 15,847 college students from 27 colleges and universities in the USA were involved in this quantitative study. According to the study, there are 8 set of ISE that have been grouped, namely (1) settling down the mechanical and electrical devices, (2) doing chemistry experiments, (3) involving the STEM groups, (4) participating in STEM competitions, (5) using STEM media, (6) talking science to peers and relatives, (7) observing animals and plants, and (8) observing stars. From this study, we know that activities (1), (2), (4), and (8) are positively related to physics identity. However, activities (7) negatively related to physics identity of college students. The study failed to give broaden information about these relationships that categorized by gender, race, language, and ethnicity.

Another impact of informal activities were studied by Gonsalves et al. (2022), particularly was informal physics learning (IPL). A collective case studies were conducted by the reserachers to explore 6 young women who were joining the IPL in Sweden. The IPL includes some activities like internships in university labs, participation in associations, and summer schools. The results showed that the IPL might be a valuable resource for young women working on their identities in physics. These resources can help them with their continuing identity work in physics as well as their pathways within the field. However, there is a report that the IPL is often inaccessible for most students. For instance, many of the interviewees reported going to significant frustrates to get internships, including traveling across the nation to investigate potential possibilities, or being chosen by instructors to attend research visits or summer schools abroad.

A study conducted by Wulff et al. (2018) explored an impact of Physics Olympiad involvement to support physics identity development of young women in German. An intervention was designed by the researcher in the form of activities namely carrying out hands-on activity, implementing cooperative method, and motivating and relevant physics content. All young women who reached the second round of the 2015 German Physics Olympiad and were eligible to participate in the next year were involved in this study (N=31). Before and after the intervention, the participants completed pre- and post-surveys with all relevant measures. The results discovered that the

intervention had significant impact on constructing physics identity, particularly in interest, recognition, and competence. Nevertheless, the study had limitation which was related to the sample size. All in all, the study provides understanding on how to address issue to engage young women in physics and improve gender equity in physics olympiad.

Another experiences of women in undergraduate was taking on managerial or leadership role in the labs. Stump et al. (2023) explored the impact of taking these roles on physics identity development of women. A mixed-method approach with surveys and interviews was used in this study. The sample of study was undergraduate students at Cornell University who enrolled in a calculus-based course. Around 14 students agreed to participate and a half of them interviewed. By using the practice-linked identity framework, the physics identity develops through students' engagement in particular practice. The study revealed that taking on managerial or leadership in labs might have positive impact on women's development of physics identity. They feel more confidence in their physics abilities. However, taking these roles has become a challenge, especially for women. Being unable to do heavy work in the lab is often experienced by women in labs.

All recent review talking about non-academic programs that influence the development of physics identity of students. However, a study of Munfaridah and friends (2022) was different. She designed course incorporating the use of multiple representations (MR) in introductory physics course. This study explored on how pre-service physics teachers develop their physics identity as well as physics teacher identity. The study employed a quasi-experimental design with pre-test and post-test. Around 61 of first-year undergraduate students in State University of Malang Indonesia were involved in this study. A modified physics identity questionnaire, a conceptual understanding test, and a survey of the use of MR were used to collect data. The study was conducted during four weeks with 200 minutes per each meeting. The result showed that the use of MR positively impacts on physics identity development of students, particular in interest and competence. The MR used also increase student's engagement in physics and improve their understanding and problem-solving skills. However, the study failed to provide details of information whether the differences of physics identity development before and after intervention that are caused by using MR. The study also suggests to compare control and experimental group for further study.

Another ASEAN study about physics identity development was in China. The study of Wang et al.

(2022) examined the effect of high-stakes testing (HST) on physics identity of Chinese students before and after the Gaokao. The Gaokao is China's national college admission examination, and it is one of the most difficult examinations in the world. Every year, millions of students take the exam, and the results decide which colleges and majors the students can apply for. In China, the Gaokao is seen as an important aspect in deciding a student's future career and social status. The sample of this study included high-school and college students in China. We review only the effect of the HST on college students, so around 233 undergraduate students of physics department were volunteered in this study. According to the study, HST has a detrimental influence in college student's physics identity. The study discovered that when college students in China transitioned from an HST-oriented educational setting to a nearly HST-free one, their physics identity degraded. In addition, the HST-oriented environment that the college students established in high school and took with them to college did not match the HST-free environment. College students learnt physics less efficiently and attentively because there was no substitute motivating force to replace the void left by the loss of HST.

All in all, the findings of the studies synthesized in this section provide evidence that informal and formal programs has powerful impact on student's physics identity development. Although not all informal programs positively increase the development of physics identity, these programs do have an impact, although not significant. In addition, most of the study occurred in the USA and European country, only limited study had done in ASEAN country, specifically in Indonesia. For further study, Indonesian researchers can take part in studying various informal activities that have succeeded in developing the physics identity of undergraduate students, where studies on informal programs in Indonesia remain scarce. Moreover, studies on the development of physics identity in formal classes are still relatively rare. This can be an insight for designing programs in the department to develop students' physics identities.

What factors does influence the development of student physics identity?

A study of Hazari et al. (2020) examined the factors that influences physics identity of undergraduate physics students. The sample of this study included 1,422 female undergraduate students in physics program in the USA and Canada who were participated in national conferences. Using mixed-method approach, both quantitative and qualitative were performed. A large-scale survey was conducted to obtain quantitative

data. The data obtained were analyze using a Structural Equation Model (SEM) to examine the relationship between the factors forming the identity of physics and then were confirmed using Confirmatory Factor Analysis (CFA). The findings elucidated that interest, recognition, performance/competence, and sense of belonging have an impact on physics identity development of female undergraduate students. Eventhough interest did not show direct relation to the development of physics identity, but recognition and performance/competence were different. These two factors have direct effect to the physics identity formation for both junior and senior female students. In addition, sense of belonging only have direct effect to the development of physics identity for senior students.

Bøe (2023) identified the factor that influences on physics identity formation, namely recognition. The study was conducted over two period of years 2016-2018 on four high-achieving physics students in Oslo Norway. Data obtained from 12 semi-structure interviews. The results elucidate that recognizing as clever students are found difficult for them because this pushes them to interact with physics in certain ways, such as emphasizing top grades and getting admit to reputable university. Having good grade in the test and examination were important for them, and being high-achieving in physics give them recognition from peer, family, and themselves. However, this study only involved 4 students where the results obtained were based on the experience they had. The results obtained may be biased and inconsistent.

Similar findings found in study that carried out by Bottomley et al. (2023) related to the impact of recognition on physics identity of students. A total of 449 students (from UK universities) were filled the survey given, but only 393 partisipants were included in this study. The study used a longitudinal survey method to investigate the correlation between gender and academic performance in undergraduate physics students. The Mann-Whitney U statistical tests were employed to investigate gender differences in physics identity, perceived recognition, and self-efficacy. Regression analysis was also employed in the study to figure out if academic achievement influenced students' attitudes. From this study, there are two factors that influences the development of physics identity, namely self-efficacy, and perceived recognition. Self-efficacy refers to a student's confidence in their ability to perform physics-based tasks. Meanwhile, perceived recognition as a physicist was connected to the students' perceptions that others regard them as a physicist. The reseachers acknowledged that the study had limitation, including small sample used and suggest for further study to

investigate or design effective interventions to promote physics identity development.

Another study was carried out by Hazari and friends (2010) examined the factor that influences the development of physics identity on college students who had taken high-school physics course. The study employed a quantitative method that include examining survey data. Only 3,829 of the 6,860 students who completed surveys and had taken high school physics were included in the analyses. These individuals attended 34 colleges and universities around the United States that were chosen randomly. This study found that high-school experiences and career intentions contribute to physics identity construction. There are several physics classroom practices that influence physics identity development, such as emphasizing on conceptual understanding, encouraging students, and asking students to take a role as expert. Teachers need to provide students with wide opportunities to get recognition and focus on practices that emphasize in improving competency.

Another study examined factor that influences physics identity development of female students was carried out by Hazari et al. (2017). The survey was conducted to gather information about undergraduate female applicants for the Conferences for Undergraduate Women in Physics (CUWiP) in fall of 2013. The study aimed to explore what motivation they had to participate in this event, and connect it to the physics identity development. Around 1033 undergraduate female applicants, only 962 students were completed the survey. The regression analysis was performed to analyse the data. From the result, it discovered that there are two significant factors that predict physics career intention, such as physics career interest at the high school and recognition from high school physics teachers. As a result, the study suggests that recognition from others, especially high school physics teachers, can play an essential role in forming female students' physics identities and attracting them to physics careers.

To sum up, the findings of these five studies pointed several factors that influences the development of physics identity on students in overseas, such as recognition, performance/competence, high school experiences, career intentions, physics career interest, and recognition from high school teachers. All in all, recognition is the most important factor that influence physics identity development of students.

What do we do next?

In synthesizing the existing studies about physics identity development, one thing becomes clear that: physics identity of students might be developed by involving in informal or formal academic programs.

Informal programs include out-of-class science experiences, learning assistant program, physics community practices, and labs' assistant or manager (Close et al., 2016; Fracchiolla et al., 2020; Lock et al., 2019; Stump et al., 2023). Meanwhile, formal programs include physics class, physics olympiad, and internship program (Munfaridah et al., 2022; Purwaningsih et al., 2020; Wulff et al., 2018). Overall, the outcomes of the review show that when students involved in one of these programs, they more engage with physics, and become interest in physics. Such an intrinsic motivation increases their performance/competence which was one of dimensions of physics identity (Guido, 2018).

Indonesia has various informal physics programs, even though their availability and scope may range across different locations and educational institutions. In fact, in Indonesia, participating in this informal program is considered less attractive to students. There are several reasons students are not interested in joining this program, such as limited awareness, perceived irrelevance or difficulty, limited access and availability, cultural and social factors, and need for academic focus. This is evidenced by the lack of enthusiasts enrolling in the Merdeka Campus program sponsored by the Indonesian government (Ika et al., 2022).

In addition, the formal programs also have influence to the development of physics identity on students. In the teacher preparation study program, the internship program is one of the programs that can sharpen student identity, especially physics. During the program students act as teachers, and apply what they learn at university to the field. Of course, this is inseparable from the ability to convey physics concepts, how to engage students to be able to interest in physics. However, they feel not confidence to be practical teacher when doing internship program due to the lack of knowledge (Munfaridah et al., 2022; Purwaningsih et al., 2020). One of the reviewed studies discovered that focusing on student' understanding will impact on physics identity development (Hazari et al., 2010). However, there is no clear information what teaching method that have an impact on physics identity.

Several studies reported that students less interest to physics. The reasons are negative perception in physics (Gudyanga et al., 2015), negative experiences in physics (Fisher et al., 2022; Purwaningsih et al., 2020), teaching methods (Guido, 2018), and personal preferences (Hazari et al., 2010). All of these will have an impact on physics identity development of students. According to researchers' interview on several students in physics education program related to their perception in physics, some of the respons were negative. First, physics is seen as difficult subject. It has complex concepts and need advanced mathematical skills.

Second, then they go to the physics department because it is a second choice, not the first. Therefore, they have to deal it.

Then, based on the result of review study, giving recognition to the students could affect physics identity development of students. Recognition means acknowledging or appreciating student's achievements, skills, and contributions in physics context (Bøe, 2023; Hazari et al., 2017; Hazari & Cass, 2018). In general, recognition can come from friends, teachers, and even family. This recognition plays a role in the validation of students' skills and abilities. Therefore, students will increase their motivation and engagement in physics (Li & Singh, 2022). They have sense of belonging and community (Avraamidou, 2020). The importance thing is recognition contributes to the physics identity formation of students (Hazari et al., 2017; Lock et al., 2019).

From the reviewed studies, it clearly can be seen that study about physics identity in Indonesia remain scarce. Within 10 years, only a few physics identity studies have been carried out in Indonesia. This needs to be a concern for institutions in Indonesia, especially the teacher preparation program. As a study program that will produce future teacher candidates, especially pre-service physics teacher. The physics department needs to pay attention to the study of physics identity development on students.

Conclusion

The outcomes of this review study provide evidence that studies about the importance of physics identity development on student in university. There are several ways for students' physics identities to develop. By involving in informal physics program and/or in formal program might be impact on physics identity development. Some obstacles will occur during the process of the development. This is influenced by several aspects, including the provision of recognition, self-efficacy, interest, and performance/competence. In addition, majority of studies about physics identity conducted in the USA and Europe countries. Only small fraction studies were conducted in ASEAN country, particularly in Indonesia. Moreover, most of the studies included high-school students, only small number sample were college students. Therefore, there is a need in exploring physics identity development among university students, especially in Indonesia. In summary, this comprehensive study has significant implications for educational policymakers, curriculum designers, physics educators, and researchers in Indonesia. The study provides evidence-based insights which improve physics education, engage more

students, and increase the number of students who pursue careers in physics.

Author Contributions

All authors have contribution to complete the manuscript.

Funding

There is no source of funding for this study.

Conflicts of Interest

There is no conflict of interest.

References

- Avraamidou, L. (2020). "I am a young immigrant woman doing physics and on top of that I am Muslim": Identities, intersections, and negotiations. *Journal of Research in Science Teaching*, 57(3), 311–341. <https://doi.org/10.1002/tea.21593>
- Bøe, M. V. (2023). Staying recognised as clever: high-achieving physics students' identity performances. *Physics Education*, 58(3), 035012 (6pp). <https://doi.org/10.1088/1361-6552/acbad9>
- Bottomley, E., Kohnle, A., Mavor, K. I., Miles, P. J., & Wild, V. (2023). The relationship between gender and academic performance in undergraduate physics students: the role of physics identity, perceived recognition, and self-efficacy The relationship between gender and academic performance in undergraduate physics student. *European Journal of Physics*, 44(025701), 1–18. <https://doi.org/10.1088/1361-6404/aca29e>
- Close, E. W., Conn, J., & Close, H. G. (2016). Becoming physics people: Development of integrated physics identity through the Learning Assistant experience. *Physical Review Physics Education Research*, 12(1), 1–18. <https://doi.org/10.1103/PhysRevPhysEducRes.12.010109>
- Fisher, C. R., Brookes, R. H., & Thompson, C. D. (2022). 'I don't Study Physics Anymore': a Cross-Institutional Australian Study on Factors Impacting the Persistence of Undergraduate Science Students. *Research in Science Education*, 52(5), 1565–1581. <https://doi.org/10.1007/s11165-021-09995-5>
- Fracchiolla, C., Prefontaine, B., & Hinko, K. (2020). Community of practice approach for understanding identity development within informal physics programs. *Physical Review Physics Education Research*, 16(2), 1–29. <https://doi.org/10.1103/PhysRevPhysEducRes.16.020115>
- Gonsalves, A. J., Johansson, A., Nyström, A., & Danielsson, A. T. (2022). Other spaces for young women's identity work in physics: Resources

- accessed through university-adjacent informal physics learning contexts in Sweden. *Physical Review Physics Education Research*, 18(2). <https://doi.org/10.1103/PhysRevPhysEducRes.18.020118>
- Gudyanga, A. (2017). Zimbabwean female participation in physics : The influence of identity formation on perception and participation. *Cogent Education*, 88(1), 1–18. <https://doi.org/10.1080/2331186X.2017.1320843>
- Gudyanga, A., Adam, K., & Kurup, R. (2015). Zimbabwean Female Participation in Physics : The Influence of Context on Identity Formation Zimbabwean Female Participation in Physics : The Influence of Context on Identity Formation. *African Journal of Research in Mathematics, Science and Technology Education*, 19(2), 172–184. <https://doi.org/10.1080/10288457.2015.1050805>
- Guido, R. M. D. (2018). Attitude and Motivation towards Learning Physics. *International Journal of Engineering Research & Technology (IJERT)*, 2(11), 2087–2094. <http://arxiv.org/abs/1805.02293>
- Hazari, Z., Brewe, E., Goertzen, R. M., & Hodapp, T. (2017). The Importance of High School Physics Teachers for Female Students' Physics Identity and Persistence. *The Physics Teacher*, 55(2), 96–99. <https://doi.org/10.1119/1.4974122>
- Hazari, Z., & Cass, C. (2018). Towards Meaningful Physics Recognition: What does this recognition actually look like? *The Physics Teacher*, 56(October 2018), 1–6. <https://doi.org/10.1119/1.5055325>
- Hazari, Z., Chari, D., Potvin, G., & Brewe, E. (2020). The context dependence of physics identity: Examining the role of performance/competence, recognition, interest, and sense of belonging for lower and upper female physics undergraduates. *Journal of Research in Science Teaching*, 57(10), 1583–1607. <https://doi.org/10.1002/tea.21644>
- Hazari, Z., Dou, R., Sonnert, G., & Sadler, P. M. (2022). Examining the relationship between informal science experiences and physics identity: Unrealized possibilities. *Physical Review Physics Education Research*, 18(1), 1–14. <https://doi.org/10.1103/PhysRevPhysEducRes.18.010107>
- Hazari, Z., Sonnert, G., Sadler, P. M., & Shanahan, M. (2010). Connecting High School Physics Experiences , Outcome Expectations , Physics Identity , and Physics Career Choice : A Gender Study Department of Mathematical Sciences , Clemson University , Clemson , Department of Elementary Education , University of Alber. *Journal of Research in Science Teaching*, 47(8), 978–1003. <https://doi.org/10.1002/tea.20363>
- Ika, Y. E., Laka, A. F., Supardi, P. N., & Rendo, D. (2022). Persepsi mahasiswa pendidikan fisika universitas flores tentang program merdeka belajar-kampus merdeka (mbkm). *OPTIKA: Jurnal Pendidikan Fisika*, 6(2), 158–167. <https://doi.org/10.37478/optika.v6i2.2194>
- Irving, P. W., & Sayre, E. C. (2015). Becoming a physicist: The roles of research, mindsets, and milestones in upper-division student perceptions. *Physical Review Special Topics - Physics Education Research*, 11(2), 1–21. <https://doi.org/10.1103/PhysRevSTPER.11.020120>
- Li, Y., & Singh, C. (2022). Do female and male students' physics motivational beliefs change in a two-semester introductory physics course sequence? *Physical Review Physics Education Research*, 18(1), 1–17. <https://doi.org/10.1103/PhysRevPhysEducRes.18.010142>
- Lock, R. M., Hazari, Z., & Potvin, G. (2013). Physics career intentions: The effect of physics identity, math identity, and gender. *AIP Conference Proceedings*, 1513, 262–265. <https://doi.org/10.1063/1.4789702>
- Lock, R. M., Hazari, Z., & Potvin, G. (2019). Impact of out-of-class science and engineering activities on physics identity and career intentions. *Physical Review Physics Education Research*, 15(2), 1–11. <https://doi.org/10.1103/PhysRevPhysEducRes.15.020137>
- Moshfeghyeganeh, S., & Hazari, Z. (2021). Effect of culture on women physicists ' career choice : A comparison of Muslim majority countries and the West. *Physical Review Physics Education Research*, 17(1), 1–19. <https://doi.org/10.1103/PhysRevPhysEducRes.17.010114>
- Munfaridah, N., Avraamidou, L., & Goedhart, M. (2022). Preservice Physics Teachers ' Development of Physics Identities: the Role of Multiple Representations. *Research in Science Education*, 52, 1699–1715. <https://doi.org/10.1007/s11165-021-10019-5>
- Prefontaine, B., Mullen, C., Güven, J. J., Rispler, C., Rethman, C., Bergin, S. D., Hinko, K., & Fracchiolla, C. (2021). Informal physics programs as communities of practice: How can programs support university students ' identities? *Physical Review Physics Education Research*, 17(2), 1–21. <https://doi.org/10.1103/PhysRevPhysEducRes.17.020134>
- Purwaningsih, E., Suryadi, A., & Munfaridah, N. (2020). "I am a Rhetoric Physics Student-Teacher": Identity

- Construction of an Indonesian Physics Student-Teacher. *Eurasia Journal of Mathematics, Science and Technology Education*, 16(12), 1-14.
<https://doi.org/10.29333/ejmste/9123>
- Randolph, J., Perry, J., Donaldson, J. P., Rethman, C., & Erukhimova, T. (2022). Female physics students gain from facilitating informal physics programs. *Physical Review Physics Education Research*, 18(2), 1-12.
<https://doi.org/10.1103/PhysRevPhysEducRes.18.020123>
- Stiles-Clarke, L., & MacLeod, K. (2016). Choosing to Major in Physics, or Not: Factors Affecting Undergraduate Decision Making. *European Journal of Physics Education*, 7(1), 1-12.
<https://doi.org/10.20308/ejpe.95844>
- Stump, E. M., Dew, M., Jeon, S., & Holmes, N. G. (2023). Taking on a manager role can support women ' s physics lab identity development. *Physical Review Physics Education Research*, 19(1), 1-18.
<https://doi.org/10.1103/PhysRevPhysEducRes.19.010107>
- Trujillo, G., & Tanner, K. D. (2014). Considering the role of affect in learning: Monitoring students' self-efficacy, sense of belonging, and science identity. *CBE Life Sciences Education*, 13(1), 6-15.
<https://doi.org/10.1187/cbe.13-12-0241>
- Veloo, A., Nor, R., & Khalid, R. (2015). Attitude towards physics and additional mathematics achievement towards physics achievement. *International Education Studies*, 8(3), 35-43.
<https://doi.org/10.5539/ies.v8n3p35>
- Wang, J., Li, Q., & Luo, Y. (2022). Physics Identity of Chinese Students Before and After Gaokao: the Effect of High-Stake Testing. *Research in Science Education*, 52(2), 675-689.
<https://doi.org/10.1007/s11165-020-09978-y>
- Wulff, P., Hazari, Z., Petersen, S., & Neumann, K. (2018). Engaging young women in physics: An intervention to support young women ' s physics identity development. *Physical Review Physics Education Research*, 14(2), 1-18.
<https://doi.org/10.1103/PhysRevPhysEducRes.14.020113>