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DEVELOPMENT AND VALIDATION OF A SCALE TO MEASURE UNDERGRADUATE STUDENTS' PHYSICS IDENTITY

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ABSTRACT

Introduction: Through physics education students are helped to realize the relevance of physics and technology to their lives, and this will encourage them to willingly continue their physics study in or beyond school. So, it is very important to have instrument with validity evidence that can be used to investigate physics identity effectively and efficiently.
Purpose: This study made use of information from prior research to adapt, test and validate items for a physics identity instrument to be used with undergraduate students offering physics in their first year.
Methodology: This is a survey study using an ex-post facto approach. A total of 400 participants were selected using the simple random sampling technique. The reliability, content validity, face validity, and construct validity of adapted scale were computed. SPSS AMOS version 23 was used for performing exploratory and confirmatory factor analyses.
Result: The new scale "SPIQ" consists of 15 items under three sub factors: interest, recognition and self-efficacy. The model with 15 items of SPIQ scale was validated by confirmatory factor analysis and showed a good fit. The Cronbach's α for the overall scale was 0.87, and 0.80, 0.88, and 0.89, respectively for scale under interest, recognition and self-efficacy respectively.
Conclusion: The "SPIQ" is a valid, reliable scale to assess the 'physics person' of undergraduate students.
Recommendation: Given the role physics identity play in students continued interest, engagement and participation in physics, it is important for educators, researchers and policy makers to explore students' physics identity.

Keywords: Physics identity; Undergraduate students; EFA; CFA; Physics achievement

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PUBLIC INTEREST STATEMENT

By engaging in social interactions, people learn by making sense of their experiences that help them function in the world around them. Students' Physics identity is informed by four sources: self-image, expectations about their roles and behaviours, perception of how others view them and experience of interacting with others. These sources shape the identity in terms of feelings of belonging and being capable. To measure characteristics of a large population, a survey instrument is the natural choice. Hence, an instrument needs to be developed to measure learners' physics identity useful for gathering information that can guide teachers in improving their teaching practices and help to evaluate the effectiveness of physics educational interventions.

INTRODUCTION

Students are shaped by their physics culture. The culture of physics is immersion into a well-established system of behaviours, meanings, and beliefs rather than merely instruction in a set of approved, academic courses. Students who want to be involved in the community of practice that is physics must learn the values, customs, and behaviours that are proper for this community. A student's understanding of what it takes to act and be accepted as a capable member of the community may be one of these norms. One facet of adapting into a practice community is competence. For students to become fully integrated into the physics community of practice, teachers must comprehend how students interact with, resist, and/or navigate the cultural norms of this community. After joining a community of practice in physics, students start to develop their identities as physicists.

Participation in communities of practice produces significant outcomes, including these identities. The process of conceptualizing and acting like a physicist, as well as being perceived as a physicist, is known as identity building. Since identity is shaped by context, learning in the physics classroom has a close relationship with it. Students' identity has been shown to influence students' decisions regarding their careers as well as short and long term academic goals (Hazari, Tai, & Sadler, 2007). Interest in physics, self-efficacy in physics, and perceived recognition by others as a physics person are the three interrelated dimensions that Kalender, Marshman, Schunn, Nokes- Malach, and Singh (2018) posited as part of students' physics identity. Additionally, Li and Singh, (2022) demonstrated using structural equation modelling that these three dimensions are significant predictors of the extent to which students see themselves as a physics person.

Previous studies indicate that students' self-efficacy plays a crucial role in their motivation to succeed in a given subject (Nissen & Shemwell, 2016; Marshman, Kalender, Schunn, Nokes-Malach & Singh, 2018; Marshman, Kalender, Nokes- Malach, Schunn & Singh, 2018; Sawtelle, Brewe & Kramer, 2012). Self-efficacy, in particular, is the conviction that one can succeed in a given task, course, or subject area (Li & Singh, 2023; Li & Singh, 2023). Research has indicated that self-efficacy affects students' performance and engagement in a given domain (Zimmerman, 2000; Pajares & Schunk, 2001; Zeldin, Britner, & Pajares, 2008; Britner & Pajares, 2006; Kalender, Marshman, Schunn, Nokes- Malach & Singh, 2020). When it comes to a particular subject, students who have high self-efficacy tend to enrol in more challenging courses than those who have low self-efficacy because they view challenging assignments as challenges rather than threats (Watt, 2006).

Interest is another motivating factor; it is characterized by feelings of joy, curiosity, and involvement in a certain field (Harackiewicz, Barron, Tauer & Elliot, 2002; Hidi, 2006). Research has indicated that students' learning can also be impacted by their interests (Wigfield, Eccles, Schiefele, Roeser, & Davis-Kean, 2006; Zimmerman, 2000; Hidi, 2006; Renninger & Hidi, 2011). According to Häussler and Hoffmann (2002), students' achievement can be raised by changing curriculum to encourage interest in learning and making science courses more applicable to students' daily life. In addition, studies have shown that students' interest is not independent from self-efficacy (Zimmerman, 2000; Wigfield & Eccles, 2000). According to Eccles' expectancy-value theory (EVT) (Wigfield & Eccle., 2000; Li & Singh, 2023), interest is paired well with self-efficacy as connected constructs that predict students' academic outcome expectations and career aspirations. In this theory, students' persistence and engagement in a task or field can be influenced by their expectancy of success and by their estimation of the task's value. The expectancy here refers to learners' belief in their ability to succeed in the given task (Wigfield & Eccles, 2000), which is closely related to self-efficacy. Value in this theory includes four components: intrinsic value, attainment value, utility value, and cost (Wigfield & Eccles, 2000).

Intrinsic value represents students' personal interest in the task or field. Attainment value refers to how important students themselves feel it is for them to develop mastery and do a good job in the field (Wigfield & Eccles, 2000). Utility value pertains to whether this task can help them succeed in various fields (Wigfield & Eccles, 2000). The last value component is cost, which corresponds to the negative aspect of engagement such as the amount of anxiety or opportunity cost due to the time spent on the task (Wigfield & Eccles, 2000). In the expectancy-value theory, people's learning goal, academic performance, and persistence in the field are impacted by their expectancy and the four components of value (Wigfield & Eccles, 2000).

Furthermore, it has been discovered that students' interest and self-efficacy are linked to their interactions and acknowledgment from others (Li & Singh, 2023; Hidi, 2006). People's interest in a field is initially sparked and maintained by external stimuli before becoming an individual interest according to Hidi and Renninger's four phases model of interest development (Hidi, 2006; Renninger & Hidi, 2011; Hidi & Renninger, 2006). Furthermore, verbal support from others can influence an individual's self-efficacy, based on Bandura's social cognitive theory (Li & Singh, 2023). Students' perceived recognition not only strongly predicts their physics identity, but also their physics interest and self-efficacy, according to Kalender's physics identity framework (Kalender, Marshman, Schunn, Nokes-Malach & Singh, 2019). This suggests that the gender differences in students' perceived classroom experiences may account for some of the gender differences in students' physics identity, interest, and self-efficacy at the end of the course.

Previous research indicates that a student's persistence and academic achievement in STEM areas are significantly influenced by their feeling of recognition by others, such as being a science person (Cwik & Singh, 2021). Recognition from others, especially teachers and lecturers, as a physics person can be vital for student success in the physics course as well as their career aspirations. Furthermore, educators must explicitly and implicitly recognize students in order for them to feel valued as physics learners. This can be achieved by verbally praising the student's progress and accomplishments, setting high expectations for all students, and emphasizing to them that everyone can succeed in physics with hard work and resourcefulness, and the instructors are always available to help as needed (Lock, Hazari, & Potvin, 2019). Hazari, Chari, Potvin and Brewe (2020) discovered that in high school physics classes, teachers' actions obscured social boundaries between teachers and students, which in turn affected students' physics identity, which was predicted by others' recognition of the students as physics people (Hazari, Chari, Potvin & Brewe, 2020).

Students who were praised for their intelligence were shown to have a fixed attitude and to perform less well than those who were praised for their effort in a different research conducted by Li and associates (Li & Singh, 2022). However, students who were commended for their efforts were more likely to be motivated to learn the subject and to believe that their lack of success was due to insufficient effort rather than insufficient intelligence (Li & Singh, 2022). While being acknowledged as a physics person with the necessary skills to succeed in the subject can help students succeed in physics classes, receiving unfavourable recognition can be harmful to students at any level. This is particularly true for underrepresented physics students, including women.

Research has indicated that in the absence of deliberate tactics aimed at establishing an equitable and inclusive educational setting, female students do not feel suitably acknowledged even prior to their college education (Kalender, Marshman, Schunn & Singh, 2019; Bian, Leslie & Cimpian, 2017; Archer, Moote, Francis, DeWitt, & Yeomans, 2017). This is, at least in part, because of the prejudices and stereotypes that women encounter throughout their lives, as well as the unequal treatment of men and women by pre-college educators, counsellors, and other relevant parties.

The study makes use of core identity's theoretical foundations in order to operationalize physics identity. From this angle, the study investigates the ways in which identity affects people's long-term involvement in and choices about physics. For instance, Carlone and Johnson (2007) found that three constructs - recognition, competence, and performance - were significant to their participants' development of a science identity. They also observed that certain factors influenced the science identities of women of colour as they moved from college into careers in science. Hazari, Sonnert, Sadler and Shanahan (2010), however, attempted to investigate identity as a gauge of perseverance in the profession by drawing on the work of Carlone and Johnson (2007) as well as Social Cognitive Career Theory (Lent, Brown & Hackett, 1996, 194). By changing the viewpoint, interest was included as a fourth element of identity formation. The four sub-factors of physics identity were derived from these investigations as well as earlier identity research (Cribbs, Hazari, Sadler & Sonnert, 2015).

The inclusion of these criteria for identity is also supported by other research. For instance, when undergraduate students were asked what it meant to be a "math person," the majority of them said that they associated mathematics identity with performance, competence, and interest (Cribbs, Tassell, Hazari, Sadler & Sonnert, 2022). Furthermore, the study indicated that students' self-reported mathematics identity was lower when they did not receive recognition from their teachers, emphasizing the significance of recognition (Cribbs, Tassell, Hazari, Sadler & Sonnert, 2022). Cribbs, Tassell, Hazari, Sadler and Sonnert, (2022) asserted that when how identity is defined was analyzed, the four sub-factors paint a picture of the ideas people are thinking about when they ask themselves what it means to be a 'physics person', and people who are thinking back on their experiences can give examples of how those experiences have shaped who they are.

Previous research utilizing a related framework (Cribbs, Hazari, Sonnert & Sadler, 2020; Cribbs, Cass, Hazari, Sadler & Sonnert, 2016 ; Godwin, Potvin, Hazari & Lock, 2016) shows that the measure is consistent with the core identity framework and can be employed to investigate student involvement or persistence in this field of study. Previous research on identity highlights the significant influence of identity, demonstrating that it acts as a mediator between several affective metrics and academic results (such as career interest and achievement (Cribbs, Hazari, Sonnert & Sadler, 2020; Bohrnstedt, Zhang, Park, Ikoma, Broer, & Ogut, 2020; Stets, Brenner, Burke & Serpe, 2017). Together, these four sub-constructs of the physics identity scale—interest, recognition, competence, and performance—give an overview of a person's sense of self in relation to the subject matter.

Furthermore, it is crucial to comprehend the definition and context of each of these sub-constructs within earlier studies. First, a student's desire or curiosity to consider and acquire knowledge of physics is referred to as interest. Scholarly investigations have documented the significance of interest in relation to students' attention spans (Harackiewicz, Smith & Priniski, 2016), academic motivation (Ainley, 1998), profession selection (Lent, Sheu, Singley, Schmidt, Schmidt & Gloster, 2008; Renninger & Hidi, 2016; Su, Rounds & Armstrong, 2009), and identity (Mangu, Lee, Middleton & Nelson, 2015; Renninger, 2009). The definition of recognition is then extended to include students' perceptions of their own and other people's perceptions of them in connection to physics. According to Martin (2006), this sub-construct encompasses how others 'construct' us in relation to physics, which is consistent with how other scholars have discussed identity. People frequently use the expression "physics person" or "non-physics person" to talk about their own sense of self.

Wang and Hazari (2018) discovered that high school students' perceptions of physics were influenced by the manner in which teachers employed both explicit and implicit recognition tactics in the classroom. The formation of students' physics identities also depends on their perception of themselves as "good at physics" (Darragh, 2015). Students' self-perception is also shaped by their parents. Finally, students' beliefs about their comprehension of physics are defined as competence, and their beliefs about their performance in physics are characterized as performance. According to earlier studies, self-efficacy is related to one's identity (Hazari, Sonnert, Sadler, Shanahan, 2010) and is related to both competence and performance (Bandura, 1997). Competence and performance load jointly, according to earlier studies using this methodology (Cass, Hazari, Cribbs, Sadler & Sonnert , 2011). This study made use of information from prior research to adapt, test and validate items for a physics identity instrument to be used with undergraduate students offering physics in their first year.

STATEMENT OF THE PROBLEM

The focus of numerous studies conducted recently has been the significance of identity on students' future goals and academic achievement. Given the need for STEM workers and the emphasis on persistence in STEM fields—such as computer and physics-related fields, which are expected to grow at one of the fastest rates in the USA between 2021 and 2031 (U.S. Bureau of Labor Statistics, 2022), an instrument with supporting validity and reliability evidence could offer educators and researchers an effective way to explore physics identity in both formal and informal settings. Furthermore, the authors observed that compared to other research domains, there are comparatively fewer studies examining learner physics identity, based on the reviewed literature. There aren't many established metrics for physics identity at the moment. The few quantitative measures that are currently in use in the area were either validated using a different population or do not provide validity evidence. By creating a physics identity tool for undergraduate students, the current work aims to close these gaps in the literature.

PURPOSE OF THE STUDY

The purpose of this study is to develop a scale to measure undergraduate students' physics identity and evaluate its validity and reliability.

RESEARCH QUESTIONS

1. How valid is the Physics Identity scale developed for measuring undergraduate students' physics identity?
2. How reliable is the Physics Identity scale developed for measuring undergraduate students' physics identity?
3. What are the psychometric properties for the Physics Identity scale for undergraduate students?

METHODOLOGY

Design

This is a survey research design adopting ex-post facto procedure to collect data since researcher has no direct control over independent variable as its manifestation has already occurred. Using an instrument development model and exploratory sequential design, this investigation was carried out in two consecutive phases. The first phase was developing the instrument, which involved brainstorming, a literature search, and the production of items.

Population and Sample

In 2020, the questionnaire was pilot tested with four hundred and one (401) first-year physics undergraduate students, drawn from faculty of Science, Engineering, Agriculture, Education and Basic Medical Sciences of Federal University, Wukari, using simple random sampling. The data collected using the sample was used for exploratory factor analysis.

A new group of first-year undergraduate physics students received the questionnaire in 2021. The procedure was the same with what was done in 2020. All four hundred (400) students who received the questionnaire returned their responses. The data collected was used for confirmatory factor analysis.

Instrument for Data Collection

Instrument development

Examining the body of literature on identity was the first step in figuring out how scales and contemporary usage were being applied. Using items from Cribbs and Utley's work (2023) as a guide, twenty one (21) items were prepared using broad insights from every item that was looked at. The developed scale to measure Students Physics Identity Questionnaire was called 'SPIQ'.This scale has both positive (14) and negative (7) items. For each item students were asked to indicate on a five-point Likert scale of not at all true of me (1), slightly true of me (2), neutral (3), true of me (4), or very true of me (5). Negative phrasing statements scoring were done in a reverse manner to that of positive phrasing statements. The total score is the sum of all item scores and higher scores suggested a higher physics identity.

Procedures for Data Collection

In 2020, the questionnaire was handed out to four hundred and one (401) undergraduate students. The administrations took place in lectures halls. The fifteen SPIQ items were part of two page questionnaire, with information about the intent of the research and the confidentiality protocols. Students were provided with consent form to fill to indicate their interest to participate in the study. The return rate was 100%. The researchers and four research assistants participated in the administration. The procedure was repeated in 2021 with a new set of four hundred (400) undergraduate students. The return rate was also 100%.

Methods of Data Analysis

Quantitative data collected through the SPIQ was keyed into a computer and all analyses were conducted using SPSS AMOS Version 23. Exploratory and confirmatory factor analyses were carried out using data collected in 2020 and 2021 respectively. The reliability of SPIQ was estimated using Cronbach's alpha.

RESULTS

Research Question 1: How valid is the Physics Identity scale developed for measuring undergraduate students' identity?

Using items from Cribbs and Utley (2023) as a guide, twenty one (21) items were prepared using broad insights from every item that was looked at. Thus, the initial draft consisted of 21 items assessing physics identity. The face validity of the draft copy of SPIQ was assessed by obtaining feedback from three experts in physics and two experts in measurement and evaluation. For qualitative assessment, all validators were requested to evaluate the relevant wording, difficulty, and suitability of the items. In quantitative approach, they were asked to answer the question, "to what level does each of the items necessary for measuring the component of students' identity in physics? Each item was rated on a five-point Likert scale, with 1 denoting that it was entirely superfluous and 5 denoting that it was absolutely vital. The experts' opinions led to the removal of six (6) items. The final edition (fifteen items) of the

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questionnaire has logical validity index of 0.85.

Research Question 2: How reliable is the Physics Identity scale developed for measuring undergraduate students' identity?

The analysis of Table 1 revealed that each of the three components of SPIQ had a high reliability coefficient that ranged from 0.80 to 0.89. The validated SPIQ scale's total Cronbach's alpha was 0.87. The corrected item has a total correlation of 0.530 to 0.710. According to David (2016), Cronbach alpha of 0.70 and above is suitable in social sciences research. Thus, the test items in the SPIQ instrument are reliable for assessing students' physics identity.

Table 1: Reliability coefficient of SPIQ

Factor 1: Interest	**Reliability coefficient**
I wonder everyday about how physics works In general I found physics very interesting I want to know everything I can about physics. I am curious about recent physics discoveries Physics class is dull and boring	0.80
Factor 2: Recognition	
The respect I received from my peers help me to see myself as someone that can excel in physics I see myself as a physics person The value attached to my contribution by my physics lecturers, help my outlook as physicist My experiences with my family make me see myself as someone that can do well in physics. My lecturers in physics don't see my effort and improvement as good enough.	0.88
Factor 3: Self Efficacy	
I believe that I have a lot of weakness in Physics I understand concepts I have studied in physics If I encounter a setback in a physics exam, I can overcome it. I am not sure about myself in Physics problem solving I usually help my classmates when they ask for help in Physics	0.89

Research Question 3: What are the psychometric properties for the Physics Identity scale for undergraduate students?

Exploratory analysis was carried out using the data collected. Correlations between each of the measure's variables were determined in order to look at the internal structure of the construct. It was found that all correlation coefficient values fell between 0.41 and 7.6, meaning that no item was deemed to be excluded (Field et al. 2012). To ensure adequate sample and determine whether the items are suitable for exploratory factor analysis, the Kaiser-Meyer-Olkin (KMO) and Bartlett's tests were conducted. A substantial value of Barlett's test of sphericity ($\chi 2 = 3564.88$; $p < 0.001$) and a KMO value of 0.89 (with individual items at 0.75 to 0.87) indicated the adequacy of sample size.

Subsequently, promax rotation was employed by the researchers to assess each of the fifteen items through principal component analysis. The solution was deemed to be sound by the residuals and different factorability indicators, which were all positive. A scree plot likewise revealed three components, and three components with an eigenvalue greater than one were identified. Items loaded as theorized on the three sub-constructs; interest, recognition, and self efficacy. The sub-construct interest had the largest percentage of variance explained at 29.03%, while recognition and self efficacy explained 24.61% and 23.30% of the variance. The three factors explained 76.94% of the cumulative variance. As shown in table 2 and 3.

Table 2: The principal component factor analysis for SPIQ

Number	Eigenvalue	Post rotational Variance	Cumulative
Interest	4.345	29.03	29.03
Recognition	3.618	24.61	53.64
Self Efficacy	3.507	23.30	76.94

Table 3: Rotated component matrix of SPIQ

Factor	Components 1	2	3
Factor 1: Interest			
I wonder everyday about how physics works	**.849**		
In general I found physics very interesting	**.836**		
I want to know everything I can about physics.	**.897**		
I am curious about recent physics discoveries	**.778**		
Physics class is dull and boring	**.807**		
Factor 2: Recognition			
The respect I received from my peers help me to see myself as someone that can excel in physics		**.709**	
I see myself as a physics person		**.723**	
The value attached to my contribution by my physics lecturers, help my outlook as physicist		**.886**	
My experiences with my family make me see myself as someone that can do well in physics.		**.708**	
My lecturers in physics don't see my effort and improvement as good enough.		**.810**	
Factor 3: Self Efficacy			
I believe that I have a lot of weakness in Physics			**.890**
I understand concepts I have studied in physics			**.703**
If I encounter a setback in a physics exam, I can overcome it.			**.856**
I am not sure about myself in Physics problem solving			**.807**
I usually help my classmates when they ask for help in Physics			**.706**

Confirmatory factor analysis showed that factor loadings were more than 0.4 and ranged from 0.706 to 0.88 when the EFA results were cross-validated using CFA. An excellent fit model was demonstrated by the fit indices, which showed $\chi 2$ (72) = 2048.57; $p < 0.001$, GFI = 0.95, and RMESA = 0.07.
Fit indices demonstrated that the model was well-fitting.

DISCUSSIONS

The purpose of this study was to develop a new scale for evaluating students' physics identity and to test its psychometric qualities. A panel of specialists evaluated the content and face validity, while EFA and CFA determined the construct validity. The dependability of the scale was assessed by measuring its internal consistency and stability. The Cronbach's alpha for the newly designed and validated SPIQ scale was 0.87 for the overall scale and ranged from 0.80 to 0.89 for each of the three subscales.

These results indicate good internal consistency. The factor structure of the scale was tested with EFA and CFA. Factors were extracted from the items using EFA. The three sub-constructs of interest, recognition, and self-efficacy were thought to be the basis for item loading. The proposed model created from the EFA was tested using the CFA to see if it fit the data. Fit indices demonstrated that the model was well-fitting. Students' Physics Identity can be calculated using this final scale by adding up their item scores; the lowest possible total score is 15, and the highest possible score is 75. Higher overall scores indicate a more positive self-identification as a physicist, whereas lower values indicate a negative attitude toward the subject.

The findings of the present investigation align with the conceptual identity framework developed in previous identity studies involving undergraduate students (Cribbs, Hazari, Sadler & Sonnert, 2015; Godwin, Potvin, Hazari & Lock, 2016; Hazari, Sonnert, Sadler, Shanahan, 2010). Compared to earlier studies involving undergraduate students, the amount of variance explained by the three sub-factors of physics identity is different. In Cass, Hazari, Cribbs, Sadler & Sonnert (2011), interest explained the least amount of cumulative variance explained (18%) and competence performance the most (44%). Also, Cribbs and Utley (2023) reported interest to be 33%, and competence/performance to be 17%. This could be ascribed to different in subject area, demography or experiences.

CONCLUSION

The present study verified the validity (content, face, and construct) and reliability (internal consistency and stability) of the SPIQ in Nigeria context. Therefore, the "SPIQ" is a valid, reliable scale to assess the 'physics person' of undergraduate students.

RECOMMENDATIONS

Given the role physics identity play in students continued interest, engagement and participation in physics, it is important for educators, researchers and policy makers to explore students' physics identity.

LIMITATIONS

The scope of the current study was restricted to Wukari in Taraba State, Nigeria. It may not be possible to extrapolate the sample size to all global areas and populations. Previous studies have shown that racial identity, social norms, and classroom dynamics influence how students view themselves in relation to physics (Cobb, Gresalfi, & Hodge, 2009; Martin, 2019; Nasir & Shah, 2011; Oyserman & Lewis, 2017). Furthermore, this study investigated physics identity from a certain perspective known as core identity, which misses the complex picture that may be seen from several angles. Normative, core, and personal are the three constructs that Cobb and Hodge (2011) outlined for examining students' identities. Further investigation in this domain could broaden the fields' comprehension of physics identity formation and expand upon the work conducted in this study as well as the field's overall efforts.

Conflict of Interest: The authors declared no conflict of interest.

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Authors Level of Contribution:

Fagbenro waliu Ayoola drafted the proposal, developed the items in conjunction with the second author, participated in data collection and carried out the analyses

Samuel Garpiya Bileya proof read the work, refined the work for publication, participated in item development, data collection and data interpretation

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