

## **Why it should be ‘and’ not ‘or’: Physics and music**

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Participation in informal physics programs as a facilitator has an effect on a person’s identity within their own discipline. This paper discusses a case study, based on Lave and Wenger’s Community of Practice framework, with analysis of three interviews of facilitators of an Irish informal learning program for eight to twelve-year-olds that aims to combine physics and music. The facilitators are university students in Music Education, Science Education, and Physics; an interview of a facilitator from each field was used. We look to see how the differing backgrounds of each interviewee affects their science identity within the various communities they are a part of. The identity code Nexus of Multimembership is studied in detail leading to a discussion of the importance of acknowledging multimembership in informal physics programs.

## I. INTRODUCTION

A recent focus on informal physics spaces has been prevalent within the field of physics education research [1], [2], [3]. Informal environments are often distinguished from formal environments by greater degree of agency offered to the participants, as well as the facilitators who are engaging with teaching practices. By focusing on informal environments, we can study ways that university students interact with and form a physics identity outside of their usual classroom environments [4]. We are particularly interested in informal environments that provide the opportunity to engage with multiple identities that are important to students. As a person's identity is composed of many identities, how these various identities are included and acknowledged within an environment can impact their identity as a whole [5],[6]. Therefore, studying how these identities interact is important in order to provide a supportive environment for a diverse range of students and to create a wider range of voices within the field of physics.

By studying an informal program that intentionally combines music and physics, we can closely analyse student facilitators' interaction with the practices of teaching, music, and physics. In this paper, we will discuss three facilitators with different educational backgrounds (Music Education, Physics, and Science Education). By using Lave and Wenger's Community of Practice framework [7], we are able to analyse the semi-structured interviews and explore how the experience of these facilitators may have impacted their physics identity. Due to the combination of physics and music in the program 'Musical Physics'(MP), discussions of negotiation of physics identity with other identities arose naturally and prompted the research question 'How did participating in MP affect the physics identity of undergrad facilitators from different degrees?'

The following sections describe the Community of Practice framework, the Musical Physics program, and outline our methodology. The findings of this paper, including how the combination of music and physics impacted the facilitators' physics identities, will then be discussed. The final section presents our conclusions and the implications of our findings for program and classroom design.

## II. COMMUNITY OF PRACTICE FRAMEWORK

Lave and Wenger [7] defined Communities of Practice (CoP) as groups of people who have a *domain* (shared goals or expertise), *community* (ways to help each other achieve the goals) and *practice* (norms, common repertoire and shared information to achieve the domain). As members of a CoP, we build our identity as we connect to the community and practices, developing a sense of belonging by negotiating our participation in the community through the practices.

Wenger [8] identified five mechanisms within a CoP that may impact an individual's identity within that community by acting on the domain, community, and practice to help

members move in or out of the CoP. Wenger's framework has been contextualised by Fracchiolla *et al* [2] to study informal programs. In this study we will focus on the contextualized framework. The five identity mechanisms are *Relationship between Local and Global* (RbLG) which refers to an individual's negotiation of their local ways of belonging and how that fits to a broader spectrum of practices, styles, and discourses; *Negotiated Experience* (NE) is related to an individual's interactions with other members of the CoP and how they affect the individual's view of the CoP; *Community Membership* (CM) is about the forms of competence developed and valued by participants in the community; *Learning Trajectory* (LT) refers to events that have taken place in the past or things that have been learned that resulted in the participant becoming a member of the CoP; and *Nexus of Multimembership* (NM), which is the focus of this paper, is how an individual, composed of multiple identities, negotiates being a member of two or more communities and how their role serves as a bridge between those communities. Each of these five codes has three subcodes; in, out, and neutral, which denote positive, negative or indistinguishable between positive and negative, movement in the corresponding CoP. Only one identity subcode can be used at a time.

Community codes are used to identify which CoP is being discussed at various times. Multiple communities can be coded together. In this paper, we focus on the Physics community but the interviews were also coded with codes corresponding to the Musical Physics, Informal/outreach, Music, and Discipline (referring to the subject's university major) communities. Community codes were assigned when a facilitator discussed an experience that was within a certain community or affected their membership of a community. For this study, the physics community is defined with a domain of supporting and growing the knowledge of the physics community by formal and informal means and wanting to learn more physics. The community is made up of physicists, students, and the general public who want to learn more physics through formal or informal means, keeping up to date with recent discoveries and attending public engagement events. Inward movement into this community is deemed a strengthening of an individual's physics identity.

## III. MUSICAL PHYSICS PROGRAM

Musical Physics is an informal learning program for eight to twelve-year-old Irish children based on the question 'what do music and physics have in common?'. The program aims to show that music and physics are connected and spread the message that it is acceptable to love both subjects. The facilitators are undergraduate students drawn from two Irish universities, one providing music education students, the other science education students, and both providing physics students. A professional musician and graduates of the previous programs also facilitate. For each MP session the facilitators are equally distributed around their backgrounds in physics,

musics, and science education. However, all of the MP facilitators usually have some background in music, as music is a popular practice and school subject in Ireland. The facilitators join the program by completing an application which details their university degree, year, if they sing or play an instrument, and why they wish to join the program. If accepted, the students attend two training sessions where they are introduced to the main concepts and ideas of the program and the materials they have access to. They also plan specific activities for the children.

The program consists of two school visits and a workshop in a national cultural institution in Ireland, which we will call Music Hall (MH). The MH funds the MP program and provides access to three large rooms for the week of the workshops. The facilitators visit the primary schools before the workshop to prepare the children, lead the workshops in the MH where the children participate in an active learning environment, and complete a post-workshop school visit to allow reflection on what was learnt. MP is based on a co-teaching model [9] which allows the facilitators to work with the school teachers to ensure the children’s maximum engagement. Teachers’ duties include participating in the visits and workshops, teaching the children the ‘Galaxy Song’ (sung during the workshops) prior to the children’s arrival at the MH, and attending one information session about MP.

The facilitators work in pairs to design their own lessons for the school visits, based on material provided during training. During the workshops five to six facilitators work with groups of twenty to thirty children in one of the three rooms. Each room has a different, active way of combining the learning of music and physics. The children visit a room for approximately forty-five minutes. At the beginning and end of the six-hour workshops, all three groups of children gather in the largest room to sing the ‘Galaxy Song’ which is accompanied by facilitators on their various instruments of choice.

#### IV. METHODOLOGY

Semi-structured interviews of nineteen facilitators were conducted during January 2019 MP workshops. Interviews were conducted by one of the researchers on the team, lasting on average twenty-nine minutes. Interviews were designed to learn about students’ motivation for participating in the program and their discipline. Some sample questions included: ‘Why did you decide to join the program?’, ‘Did you have any hesitations about joining the program?’ and ‘How would you describe a typical physicist/musician?’. The transcripts of these interviews were divided by the interviewee’s degree: Music Education, Physics, or Science Education to test the hypothesis that a facilitator’s discipline would affect their view of the interaction of music, physics, and education.

Interviews from three students, which we will call Buttercup, Blossom, and Bubbles, each pursuing a different degree, were chosen to be analyzed. The three chosen interviews were rich in data as they specifically discussed how

their background degree affected their participation and their views around the interaction between music and physics. The amount of previous experience the interviewees had in MP was also a factor in choosing the interviews to code in an attempt to remove level of experience as a variable. Buttercup and Bubbles had participated in MP once previously and Blossom was participating for the first time. Interviews were coded independently by two researchers using the identity and community codes. There was an average of 80% interrater agreement initially. The coding of all three interviews was then discussed and disparities between the two researchers’ were resolved. For analysis purposes, the codes were normalised by calculating the percentage the individual code represents over the total amount of codes per interview.

#### V. FINDINGS

In this study, we are focusing on the Nexus of Multimembership (NM) code, because we are interested in how the interaction between Physics, Music, and Education CoPs in Musical Physics affects the facilitators’ physics identities. Figure 1 shows the frequency of the identity codes that overlapped with the Physics community code across the three interviews. For example, 33% of Buttercup’s interview that was coded with the Physics community code was also coded with the identity code Nexus of Multimembership-in.

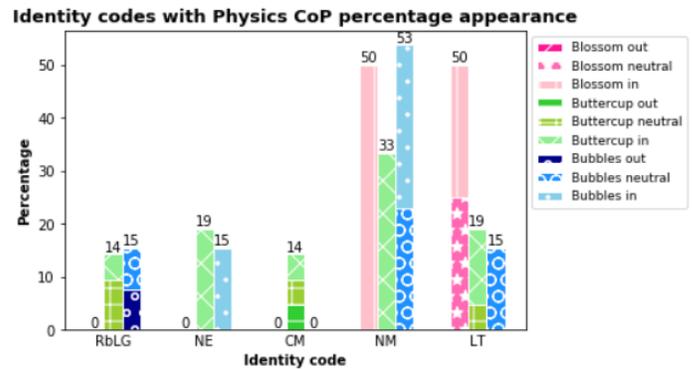


FIG. 1. Identity codes interaction with Physics CoP N=4 (Blossom) N=21 (Buttercup) N=13 (Bubbles), RbLG = Relationship between Local and Global, NE = Negotiated Experience, CM = Community Membership, NM = Nexus of Multimembership, LT = Learning Trajectory

Nexus of Multimembership was the most frequent identity code to interact with the Physics CoP in Bubbles and Buttercup’s interviews while NM and Learning Trajectory (LT) jointly had the most and the only interaction with the Physics CoP in Blossom’s interview. Thus, it is clear that the interaction between the facilitators’ identities as physicists, musicians, and educators prompted in MP had an impact on their physics identity. We now look at each facilitator in detail to examine how their physics identity developed because of MP.

### A. Blossom

Blossom, a female, first year music education student, would not have been involved in Musical Physics if it was solely an informal physics program. She had little prior physics knowledge consisting only of the basics discussed in the general science program of Irish secondary schools, and had not studied physics at university level due to her discipline. This, instead of an access barrier to being a MP facilitator, was viewed as a bonus of the program by Blossom. When speaking about why she joined the program she said:

Community: Musical Physics  
Nexus of Multimembership-in  
I obviously knew that [MP] was investigating the connections [between Physics and Music]. That was something that I thought was really interesting and I liked it because obviously I'm doing music education and I thought it'd be a great way to connect with kids who would not. Not everyone is interested just purely in music so maybe going from the aspects of science, I was interested to see would more kids be interested in it [music] and that seems to be the case from doing the school visits and the workshop.

Blossom viewed the interaction between the physics and music as a positive way to teach music. She saw learning and teaching physics as an exciting challenge and believed the physics would make the music more approachable for the children. Her desire to teach music well directly prompted the development of her physics identity. Through MP Blossom found she liked learning about physics; 'I think how much I've enjoyed actually learning about the physics and how connected they are [music & physics].' She identified strongly as a musician but recognised that being a musician was not the only identity she had to have:

Communities: MP, Discipline & Physics Interest  
NM-in  
[A]ctually just be open to learning because you're constantly learning and even to go like, because I'm studying music education doesn't mean that I can turn away from different opportunities in different areas.

Blossom's positive view on multiple identities prompted her participation in Musical Physics and the development of a physics identity. Blossom shows how the MP facilitators who did not have a physics discipline could still develop a positive physics identity.

### B. Bubbles

Bubbles is a female, second year physics and maths education student who was completing her second session of MP at the time of the interview. She admitted to struggling to keep up her music as a hobby during university;

Communities: MP, Physics Interest & Music Interest  
Nexus of Multimembership-neutral  
And I wish [...] I was able to like, be able to decide both rather than just one or the other because oftentimes and, this definitely happened to me when I went to college. I neglected my instrument, like I played the guitar and I neglected that for so long that I was like forgetting some of the things, and when I came here I was like, well I actually don't have to it I'll have to like not play an instrument or I don't have to choose one or the other I'm able to choose both.

This was coded as NM-neutral as Bubbles is speaking of how the music and physics CoPs have interacted in her life previously. While there is clear outward movement in the music CoP, the movement in the Physics CoP is unclear so a neutral subcode was used. Negotiating being a physicist and an educator, a consequence of her discipline, has also been an issue for Bubbles. She identifies as an educator first; 'I want to be a physics/math teacher. So I always say I'm a teacher first before I'm a physicist' but this has caused a negative impact on her physics identity due her peers' reactions;

Community: Discipline  
Relationship between Local and Global-out  
And it's so disheartening when they say oh you know "just teachers" or whatever. Like I've definitely had so many. Even amongst my peers, I remember one of my friends at the time was saying "oh yeah you're only doing education". I was like, "what does the only imply there?" You know, and I kind of hated that.

Bubbles' multiple identities were in discord. However, Musical Physics changed the interaction between physics, music, and education in Bubbles' life. It allowed her to be all three of these identities in a supportive environment. As Bubbles describes, MP was;

Communities: MP, Discipline, Physics Interest & Music Interest  
Nexus of Multimembership-in  
a great opportunity as well for me, to flex that muscle and say like; "I am a teacher and I'm also a musician and I'm also a physicist" and I kind of loved that appreciation and under the same roof because oftentimes they're just so disjointed.

She speaks repeatedly of her love for the MP initiative describing it as; 'one of the most enjoyable experiences I've ever had in my major'. The interaction between music, physics, and education in MP clearly impacted Bubbles' physics identity positively as shown in Fig.1 where 53% of the occurrences of the Physics community code were with the Nexus of Multimembership code, all of which were neutral or in. Being allowed to acknowledge all three of these roles through MP reinforced Bubbles' physics identity.

### C. Buttercup

Buttercup, a female, second-year physics student had more success than Bubbles at keeping up her music as a hobby during her university studies by teaching the violin, as well playing violin in an orchestra. Buttercup describes music as her break from college stress;

Communities: Discipline, Physics Interest & Music Interest  
 Nexus of Multimembership-in  
 Yeah I think definitely since I came to college, because I've been spending so much time doing maths and physics that music has kind of been my like respite from that. I'm just kind of saying you know "OK I've done eight hours of maths today I need to do something else." I mean music was kind of able to give me something that was enjoyable and fun and kind of relaxing and gave me a different kind of outlet for just kind of any stress or anything.

This was coded as NM-in as being part of the music CoP supports Buttercup's membership in the Physics CoP by providing a stress outlet. This is important as she struggles with her confidence as a physicist;

Communities: Discipline & Physics Interest  
 Community Membership-out  
 Confidence is a big [issue] probably especially being in a course it's so, I think it's like 80 percent boys or something. So there's definitely, you kind of notice, a divide. I've also noted, you know, none of my lecturers are women either, in the last two years, So that's kind of a bit daunting to kind of think "oh God" you know, "I am smart enough?", "are all these people smarter than me?", and "should I be in this course?"

Buttercup thought participating in public engagement through MP would increase her confidence like performing music does, saying;

Community: MP  
 Community Membership-in  
 because I'm always kind of nervous before I do public speaking or kind of talk in front of people and then afterwards you feel so much better about yourself. So yeah it's definitely about confidence I think, and with music as well. It's the same thing as kind of performing.

She welcomed the chance to combine both her passions through participation in MP. When Buttercup first heard of MP she;

Communities: MP, Physics Interest & Music Interest  
 NM-in  
 thought well that's perfect for me. So I looked into it and it just looked like a really kind of rewarding program, which kind of merged my two favourite things.

At the time of the interview Buttercup was returning for her second session of MP as she had enjoyed her previous experience. MP by combining music and physics allowed her to reaffirm her love for both and connect them in a way she previously had not;

Communities: MP, Physics Interest & Music Interest  
 Nexus of Multimembership-in  
 It impacts me I think just being able to kind of involve both music and science in something whereas before I've kind of been doing both but they felt kind of separate. But this is kind of like me and even I obviously I knew the connection but to kind of, kind of see it in a different from a different perspective I guess like how similar they are on why I kind of connect to both. Like the kind of problem solving side of science and curiosity and kind of made me see, "Oh yeah they are similar" because sometimes when I say to people you know, "oh I like maths and music" and they are going "that's you know two sides" you know whatever. So I think it was interesting to see from kind of a child like perspective I guess. Like there is similarities and yeah it made me realize kind of why I like both of them from kind of a deeper level of understanding.

Buttercup, the subject with a physics discipline, shows that MP can have a positive impact on physicists' physics identities. This can be seen in Fig. 1 by the lack of NM-out and NM-neutral codes. MP reaffirmed for Buttercup that it is possible for her to be a physicist and a musician, therefore strengthening her physics identity.

## VI. CONCLUSIONS

In this paper, we have shown that the interdisciplinary aspect of the informal Musical Physics program helped support facilitators' multiple identities and consequently reinforced their physics identities. That is, informal programs that combine physics with other subject areas can be used as a mechanism to promote inward movement in the physics community. A supportive learning environment should acknowledge and include an individual's many identities. We have found that positive interactions between multiple communities strengthen facilitators' physics identities irrespective of their discipline. Furthermore, we see that it is important for all physics learning spaces to be designed to include, not ignore, multiple identities, because we all are more than physicists. We need to design learning environments like Musical Physics that can support multimembership in order for students to feel included and to strengthen their sense of belonging in their multiple communities.

## ACKNOWLEDGMENTS

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