

# *The Digital Score Project: Review of Ongoing Research into Digital Score Creativity and Digital Musicianship (2022-23)*

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## ABSTRACT

This paper presents an overview of *DigiScore* research activities in the first 18 months of the project. *Digiscore* is an ERC-funded project studying the technological transformation of the music score through technology. The paper is split into three sections each dealing with a major re-search theme. The first section presents design considerations for digital scores that have emerged out of the case studies, including findings from TENOR 2022, Marseilles, and other projects that incorporated technologies such as Unity gaming engines, machine learning, robotics and EEG readers. The second section focuses on two case studies looking at the impact of this research upon inclusive and accessible music-making through digital scores. Specifically, *Digital Syzygies* – a digital score as a shared creative platform for d/Deaf and autistic musicians, and *Jess+* – an AI/Robot Digital Score that operates as a creative interface between an ensemble of musicians of mixed abilities. The final section reports on insights from a digital musicianship investigation that seeks new knowledge in the skills, perceptions, contexts, cultures, awareness and knowledges of digital musicians engaging with digital scores.

## 1. INTRODUCTION

*The Digital Score: Technological Transformations of the Music Score (DigiScore)* is a European Research Council funded research project operational between 2021-2026. The core aims of this frontier-research project are to: (1) determine scientific knowledge of how digital scores stimulate new creative opportunities and experiences within a range of music practices, (2) develop a theoretical framework for digital scores as an important transdisciplinary area of research, (3) build a scientific study of inclusive digital musicianship through the transformative potential of the digital score.

A digital score is defined by the project as *a communications interface of musical ideas between musicians utilizing the creative potential of digital technology*. The meaning of this in practice is being investigated through a

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series of practice-based case studies that place the experts at the centre of their practice. The purpose of this is to offer the musicians experiences with which to report back to the researchers of *DigiScore* by contributing to a comprehensive dataset, who in-turn synthesize the results into a developing theory.

A central theoretical construct in studying digital score music-making is that of Christopher Small's notion of *Musicking* [1]. In this book, he states that 'to music is to take part', and that taking part can happen 'in any capacity, in a musical performance, whether by performing, by listening, by rehearsing or practicing, by providing material for performance (what we call composing)'. Critically, Small stresses that 'the act of musicking establishes in the place where it is happening a set of relationships, and it is in those relationships that the meaning of the act lies'. Simon Emmerson clarified Small's principle of 'meaning' to infer the 'what you mean to me' [2], (this subtle shift circumvents the significant issues of value and who is doing the evaluation of meaning). Therefore, meaning (or the what-you-mean-to-me) is to be found in the relationships formed between the new creative acts of musicking and the technologies and media of the communications interface: the digital score.

This paper presents an overview of DigiScore research insights in the first 18 months of the project.

## 2. DESIGN CONSIDERATIONS

Over the past 18 months the DigiScore team has analysed and evaluated a total of 16 case studies. A case study is defined as an ecology of relationships between all agents involved (personnel, machines, media, music etc) therefore:

- the creation of a digital score = 1 case study ("composer's perspective")
- the performance of a digital score = 1 case study ("performer's" perspective)
- a repeat performance of a digital score with new musicians e.g. at another centre = 1 case study (performer's perspective)

The purpose of a case study is to

1. innovate DS creativity through the 7 project themes of artificial intelligence, machine learning, internet

networking, robotics, virtual and augmented reality, gaming and physical computing

2. Analyse in-vivo experience/ practitioner-knowledge using the theoretical framework (i.e. the ecology of relationships inside musicking)
3. Evaluate and enhance the theoretical framework of Digital Score
4. Build a wider understanding of the scope of digital musicianship through the creative practice associated with Digital Scores

The types of digital scores that we have studied so far have ranged from fixed media, animated scrolling scores that use a combination of standard/ Western European Art Music (WEAM) notation and graphic symbols. (Type 2 in the *DigiScore* typology [3], to Unity engine platforms supporting interactive scores that reconceptualise notation and musical direction through Non Player Characters, glyphs and graphic material (type 8), to AI and robotic based scores that co-create in real-time guided by belief systems [4] and embedded musical/ compositional behaviours (type 10).

From the analysis process introduced as the methodology of the *DigiScore* project at SYSMUS'22 [5], we are able to start to see patterns common across this range and present here some of the more critical insights as a set of design considerations [6]:

- Digital Scores are fun and engaging as evidenced by interaction with music students on our recent research tour (please see section 4.1)
- They allow for a level of complexity where the temporal stress of accuracy is handed over to the digital media, enabling the musicians to focus on the music-making
- Animated scores engaged the audience in a media space leading to expectation and macro involvement [7]
- The digital score offers existing composition and performance students the opportunity to move away from the 'culture' of contemporary composition
- Digital media supports inclusivity and accessible music-making enabling musicians from outside the WEAM culture to engage creativity with score and communicating musical ideas using a language that supports what they wish to say (rather than forcing what can be said upon them).
- Musicians (old and young) are excited about digital scores and are willing to engage openly and creativity with them (some caveats below)
- Unity engines and python platforms acutely support the reconceptualization of a music score and the

communicative parameters / language of notation (e.g. dynamics, tempo, feel, world-space)

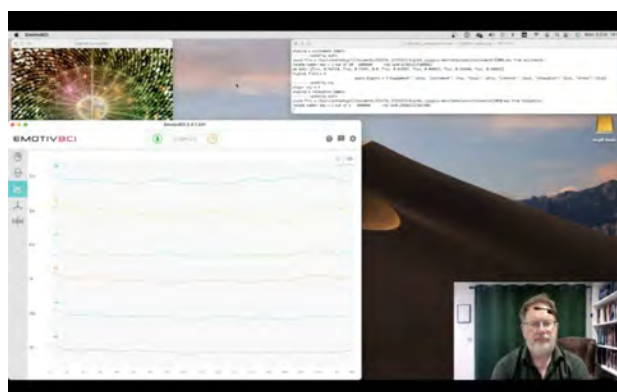
- They encourage new forms of collaboration between, say, coders and visual artists with musicians, and blur the boundaries of definitions of "composer", "performer", "audience".

But ...

- A lot of digital scores do not seem to consider the needs of the musicians that are rehearsing and then realising them, for example is it possible to rehearse a small section of a fixed-media animated score? What happens when the ensemble wishes to workshop the middle minute? How do they identify "sections" when they are reflecting, discussing and trying to improve upon your score?
- The audience is within the world of the music, but, generally does not wish to see the score – perhaps there needs to be a second visual output that is made specifically for them?
- New media and technology can be unstable, with crashing and missing adapters factored into the rehearsal process. Do you have a plan B?
- Some of the notation and conceptualisations of a digital score require a lot of explanation, and some degree of involvement with the musicians prior to engagement should be factored in.

### 3. INCLUSIVE AND ACCESSIBLE MUSICKING

We are currently involved in two case studies that deal directly with inclusive and accessible musicking through the digital score. Or more accurately, how the digital score concept and technologies can support inclusive and accessible musicking.



**Figure 1.** Andrew Hugill performing the digital score *Digital Syzygies*

#### 3.1 Digital Syzygies (2022)

The first is *Digital Syzygies*. Here we developed a Digital Score platform for shared creativity with d/Deaf and autistic musicians, that unites creativity and collective

involvement in the development of a musical idea. This Digital Score used EEG headsets to transmit musicians' brainwaves into a set of neural-controlled musical compositions and performances (see Fig 1.).<sup>1</sup>

The Digital Score project worked in collaboration with Prof Andrew Hugill (University of Leicester) to build a practice-based case study (*Digital Syzygies*) that addressed the central concerns introduced above. *DigiScore*'s principal investigator Prof Craig Vear's involvement was 2-fold: 1) providing the theoretical and conceptual guidance offered to Hugill, which supported his creativity and framing the conceptual development of *Digital Syzygies*. 2), Vear designed, developed and deployed a technical solution that facilitates the translation of brainwaves into music and supported shared creativity for the *Digital Syzygies* team, while embedding the definitions and concepts of *DigiScore*.

*Digital Syzygies* used the Emotiv Insight EEG Headset Brain Interface to connect four musicians who were remotely located (in Sweden, Sri Lanka/London, Brighton and Leicester). This technology was defined by Vear and Hugill as a novel solution with which to bind the quartet who are either autistic or are d/Deaf (Hugill is both), and as an inclusive mechanism with which to support a shared creative pursuit.

This project resulted in some transformational revelations which emerged on several levels: technical, musical and personal.

Vear's Brainwave-to-Music app supported and framed a digital score that built connections or "syzygies" between people with neurodivergent brains and hearing differences. This app was embedded with the core principles of his *DigiScore* project ensuring that it supported the *Digital Syzygies* team's development of the project. It was also designed to be a creative sandbox with which co-located musicians could share ideas.

This app supported Hugill to design a case study using the digital score format that enabled musicians to connect and see similarities in the way their neurodivergent brains react and interact with sounds. It also enabled those who are d/Deaf to relate to each other's sounds and hearing peculiarities. Overall, musicking with the help of this digital score opened many new ways to making and listening to music for the musicians of *Digital Syzygies*. On a technical level, it united d/Deaf or neurodivergent musicians in a creative space and way of working by allowing them to generate, develop and share musical ideas packaged in a novel digital and technical solution (the core definition of a digital score [1]).

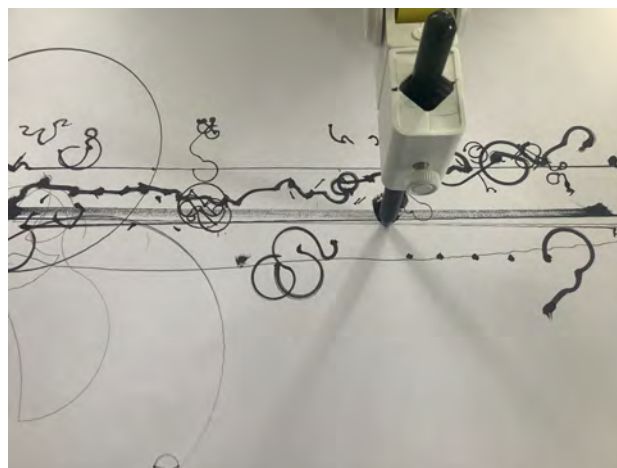
For Hugill, the digital score made him unlearn everything he has previously learned in making music as an autistic musician with hearing limitations. Such things as listening to one's instrument, listening precisely and accurately to what you're doing, and being aware of others around you are not needed from him when he makes music using this digital score. Using the digital score also

allowed him to not have to listen to sounds for long periods to make and perform music since he usually experiences pain in doing so. The digital score accessed via the brainwave reader does all the performing when it receives the sounds, Hugill can also just wear earplugs and let the brain do all the work: "I'm seeing this self-actualising brain that is making interesting music regardless of me, so it's kind of the opposite of conventional music making" (Hugill 2022). This is inevitably a new musical skill for him which he hopes to use more in his music-making from now on.

### 3.2 Jess+ (2023)

*Jess+* is an intelligent digital score system for shared creativity with a mixed ensemble of able-bodied and disabled musicians. The digital score uses AI and a robotic arm to enhance the real-time dynamic engagement of the disabled musician with the able-bodied musicians allowing her to thrive in a realtime communication beyond what has so far been possible (see fig 2.). This has flattened any hierarchy through movement and enhanced the sense of togetherness and inclusivity in musicking.

This digital score project is working in collaboration with Sinfonia Viva, Orchestras Live and Digit Music. It is involving three talented and highly experienced musicians: the disabled musician has reduced mobility and uses a powered wheelchair, her normal music engagement technology is CMPSR a modified chair joystick developed by Digit Music, and she usually engages with music by making individual pitch or chords in Ableton using the CMPSR to navigate around a Live environment. The other two musicians identify themselves as being able-bodied professional orchestral musicians who also specialise in SEN workshops.



**Figure 2.** Image of proof-of-concept version of *Jess+*, illustrating the notational language inspired by Cardew's work *Treatise*.

AI and robotic technologies are used to extend the creativity of disabled musicians. In a realtime music feedback loop, a disabled musician (A) is "plugged into" a creative

<sup>1</sup> Full details can be found here <http://www.digitalsyzygies.org.uk/>

AI robot arm that draws graphic music notation which is performed live by other musicians (B). The creative AI and the disabled musician work as an extended system, with each feeding the other: the AI reads the real-time brainwaves and arousal data of the human (A), and (A) feels the embodied behaviour of the robot arm. The feedback loop is closed as the live musicians (B) make sound, which in turn is heard by both the AI and humans (A+B). In this system, the AI and the robot arm is not an assistive tool, but rather co-creative other.

The point with this digital score is that the inked notation is only part of the score: how the arm moves, when it moves, its velocity and acceleration; how each of the marks relate to the ongoing flow, and legacy of thinking inspired by its previous marks on this paper; how the presence of the AI is continuously reading the human musicians are all elements that communicate the idea and nature of the digital score as a whole. The robot arm in this sense should not be considered an assistive tool, but a co-creative agent, as the musicians and the AI work together in a synergistic relationship to create the music.

About the AI/ robot: one musician found the AI “surprisingly communicative”. Another said that she “FELT interactive from the immediate observation that the robot’s responses weren’t purely imitating us.” [original emphasis]. She went on to say that “It seemed to ‘listen’ and reflect (for example: use a shape or stroke again later when we hadn’t repeated the music that invoked this) so this extended the ‘conversation’ between us. As a result, the creativity of the robot started to match that of the musician.”

Another musician felt that she was “in control but very collaborative”, and yet at times she wished for it to be “more demonstrative and make larger gestures to initiate a response”. On this topic, and with relation to it ‘joining in’ with the ensemble, one of the musicians wrote that “Once I got my head around not imitating what the robot was doing, I found it was rewarding and engaging to play with. The fact that it “listened” and then responded (or not!) made it easier to accept as a member of a chamber group.”

Upon reflection of their collective experiences, the disabled musician described how after a few days she is still “feeling really relaxed” because of the experience, and that it had “opened my eyes to what can be possible in ways, I hadn’t even thought about it’s like I’d met a new friend in a way.” The other musicians echoed this and wrote that it was “all very exciting”, and “mind-bogglingly inspiring and interesting”. Collectively they were looking forward to making music again in the following sessions, but crucially it is “the process that means so much and the resulting drawing an evocative memory of what happened, which is also evidence of the interaction.”

#### 4. DIGITAL MUSICIANSHIP FINDINGS FROM THE DIGIScore ROADSHOW

A large task of the DigiScore research project is the analysis of case studies, and an equally large task is the “Roadshow”. The primary aim of this task is to evaluate higher education music students’ wants and needs from digital

musicianship education across the globe through engagement with digital scores. Throughout 2021-22 we visited various institutions across Europe, and at the start of 2023, we embarked upon our first Partner roadshow of North-East America/ Canada, in association with our Canadian partner Concordia University, Montreal. Further roadshows are being planned with our other project partners for West-Coast USA (with UCSB), Australasia (with Monash), and China/ Far East (with Central Conservatory of Music, Beijing), as well as continuing our visits to Europe, and potentially India and Central and South America.

Throughout the 4 weeks, we visited public and private universities with music departments that ranged from large internationally renowned centres for innovating electronic music (such as Columbia and Carnegie-Mellon), or music performance and composition (such as Illinois at Urbana-Champaign, Northeastern and New England Conservatory), to small departments with a focus on pop music production and music business (such as New Haven). We spoke with undergraduate, and postgraduate students and PhD researchers, post-docs and faculty.

Our study of digital musicianship was understood from the perspective of ‘a person’s ability to perceive, understand and create sonic experiences’, through the broad range of musicking activities revolving around digital score creativity. We established the following areas as points of interest:

- **Skills:** what are the skills needed to articulate and interpret features and affects of digital score musicking?
- **Contexts, Cultures & Literacy:** what contextual, cultural literatures and insights are required to inspire creative thought and support musicking ideas
- **Musical Identity and Creative Practice:** what are the new modes and possibilities of creative practice?
- **Perception and awareness of (digital) music:** how do musicians actively analyse digital score music, and what interpretations are they generating when making music?

We conducted two types of polls, the first was embedded Mentimeter slides that allowed the students to engage and contribute to the discussion through the 90-minute lecture. These questions were associated with the above points of interest at appropriate points in the DigiScore lecture. This served three key purposes: 1) to gather immediate data from the students, 2) to have a higher yield of lower depth data, and to start their process of deeper thinking about the nature of their digital musicianship which we hoped would be developed in the second poll as an online questionnaire. Having started the roadshow series with only the online questionnaire we realised that yield was very poor, so the Mentimeter interactive polls, provided us with a safety net.

Overall, 60+ students engaged with the in-lecture Mentimeter polls, from which 50 completed the online form. At the time of writing the analysis of results has yet to be

completed, there are some provisional critical insights that are worth highlighting here:

#### 4.1 Mentimeter Insights

The first poll asked the question “How would you define yourself as a musician? (multiple answers possible)” (see fig 3.). This aligned with the 3<sup>rd</sup> point of interest “Musical Identity and Creative Practice” and was chosen to be the first to draw their sense-of-self directly into the discussion. The list of possible types is listed in figure 3, and this distribution was almost identically replicated across each university department. Of interest was how many students identified themselves as BOTH composer and performer, adding nuance to that identity with the remaining types (e.g. hacker). When we discussed this distribution and choice, it was revealed that any division between “composition” and “performance” pathways within a department was generally a negative divisive split. Whilst there were some monotypes who only chose “composition” or “performance”, this was generally isolated to PhD researchers, who would naturally be focused on their field of study.

How would you define yourself as a musician?  
(multiple answers possible)

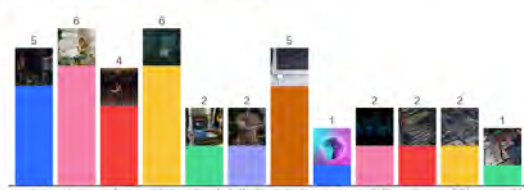


Figure 3: 1<sup>st</sup> slide from the DigiScore roadshow questioning strategy.

The second poll followed a series of slides that outlined the continuum of types of digital scores, from type 1 “The Digitised Score”, to type 4 “The Animated Score”, to type 6 “The Creative System”, to type 10 “The Living Score”. This question asks them “What skills do you have that could help you with digital score creativity?”, and was immediately followed by a slide that asked, “What digital music skills would you like to have?”. A major theme in this poll was the repeated focus on AI, data and coding skills. When questioned whether this was because the final digital score example focused on AI and robotics had skewed their answers, the majority of students responded that it was more to do with critical skills they are being told are crucial for the workplace in general. Our observation here is that music is a great laboratory with which to learn about AI, data and coding in composition, performance and musicological studies. If implemented in the curriculum could be a very popular programme.<sup>2</sup>

The third poll focused on surveying the underlying cultures and contexts that inspire these musicians to make

music. This was a broad litmus test asking them to choose one or more of the following:

- Types of music/ musicians
- Books/ theories
- Art forms (art, theatre, dance etc)
- Media (film, gaming, video etc)
- Nature and the environment (this one was added half way through the roadshow and was inspired by Seth Cluett at Columbia)

Overall, music/ musicians were the dominant choice, but not by much. Generally, only peeking over the top of others by 1 or 2 counts. With the others generally coming out equal. One conclusion is that, as the world gets smaller due to the internet and knowledge becomes readily available due to the internet, and other musics and cultures are within grasp, because of the internet, we have a pluralistic society that is taking inspiration from many more sources than merely music studies.

The final poll was the weakest in terms of the core question that it asked, but the responses were always surprising, so it wasn’t replaced. The question asked, “What do you value most in your music-making” was designed to address the fourth point of perception and awareness. The expected responses were to do with core skills of music engagement, but the reality was that they focused almost exclusively on themes of “musical soul”, “human connection”. “emotion”, “experience”, “multi-disciplinarity”, “my creative voice” or “honesty”.

#### 4.1 Online Questionnaire insights

There were two online survey questionnaires made for the roadshow tour, one addressing the students who would attend the DigiScore lecture and another to collect responses from the students participating in the workshop with digital scores. Since we presented lectures to more students than to workshop participants, we received more responses from the Digital Musicianship Questionnaire.

The Digital Musicianship Questionnaire followed a similar logic of questioning strategy as the one targeted through the Mentimeter polls. While the questions were similar, they allowed for a more in-depth description of each participant’s digital/musical skills, the context in which they are creating, their digital music identity/creativity as well as knowledge and awareness of their music practice. Besides more traditional music skills, it was noticed that the majority of students already have some digital music skills such as DAW, mixing/producing, MIDI and Max/MSP/Pure Data skills. A lesser number of students expressed proficiency in coding, however, some expressed a desire for acquiring those skills. This aligns well with some of the Mentimeter poll answers where students generally expressed a desire for more coding, AI and

<sup>2</sup> As is evident in the University of Illinois’s Computer Science and Music degree

<https://cs.illinois.edu/academics/undergraduate/degree-program-options/cs-x-degree-programs>

machine learning skills in higher education. Another, correspondence to the Mentimeter poll that was answered in more depth in the surveys was to do with students' digital music identity/creativity. A lot of the students see themselves not just as instrumentalists/composers but as music producers and creative technologists. Thus, the use of digital technology greatly augments and changes how these musicians see themselves. Based on our classroom discussions and survey responses, it seems like most of the students are aware of how the tools of digital technology shape their musicianship, citing "a learning tool for shaping own's musicianship" and allowing for "flexibility in one's music-making". Similar to the Mentimeter poll but in more depth, when evaluating what one finds important in one's music, most students answered personally citing, "fun", "authenticity", "originality", "passion" and "self-expression".

When it came to the Digital Musicianship Workshop Questionnaire, we had fewer responses, but they were valuable in assessing how the digital scores presented to the musicians engaged them in the process of music-making. This is also an important part of *DigiScore* research, gathering evidence on the connections, experiences of flow and the transformative effect digital scores have on musicians. Thus, the first two questions addressed musicians' *creativity*, looking at the kinds of relationships musicians formed with the materials of the digital scores and how the digital score engaged the musicians in musicking. Part three asked them to reflect on any new musical experiences they might have had with the digital scores that could be thought of as transformational, mentioning a digital score in particular that had that effect. In addition to these questions, we were also interested to know what musicians might need from higher education, in general, to facilitate their engagement with digital scores in the future.

Overall, the above questions were answered in greater depth and some trends that emerged from them reflect our impressions from the workshops: musicians preferred scores with clear instructions, which facilitated a fun and engaging experience for them. In addition, they found video games' format engaging where some of the behaviours of video games (such as pursuing a goal, or 'winning') add to the excitement of taking part in playing the digital score.

## 5. CONCLUSIONS

Although this project is still in the relatively early stages, it is possible to conclude the following. However, we stress the need to be open about these insights and to move away from them if required as new insights emerge over the coming years if they present challenging or contradictory evidence. From a creativity perspective, digital scores are proving themselves to be engaging and versatile. They are supporting new expressive ideas and new cultural voices. The case studies we have thus far conducted are enhancing musicians' creativity and supporting interdisciplinary collaboration. Creating digital scores through innovative use of digital media and technology does, however, come with

a new set of concerns and responsibilities for those constructing them (what we have called composers) and those realising them (performers). We are starting to see a trend where this divide of "composer" and "performer" is divisive and unhelpful with digital score creativity, and this is leading to false expectations and negative enactment. The solution we are seeing emerge is more interactive and collaborative discussion and involvement between the musicians so that the needs of the realising musician ("performer") are embedded into the core construction of the digital score. Additionally, as a lot of digital scores deal with rich media and audience-friendly spectacle, should their experience be factored into the construction? For example, should they simply watch the digital score as shown to the "performers" or could there be a parallel version that heightens their involvement in the experience of the music?

The *DigiScore* project has focused on inclusivity and accessibility, and this is something that will grow over the coming years. In the 2 case studies presented in this paper, it is evident that the digital score format and approach are enhancing musical engagement for those involved. It is flattening any hierarchy of creativity and expression by neutralizing the specialism and training needed to share and communicate musical ideas (the core definition of a music score). Additionally, binding assistive and digital technology into the fabric of a digital score system, perhaps with AI, is amplifying the communicative interactions between musicians regardless of ability.

Finally, by evaluating digital musicianship through digital score creativity we can start to see patterns that suggest it is shifting across 4 realms: skills, contexts, identity, and awareness. However, we wish to stress that these four realms are immutably interconnected and should not be isolated to the point of exclusivity of the influence of others. For example, skills that are enacted in real-time are done so because of the individual's context and education, which has informed how they perceive and what they are focusing their awareness on.

There are more insights to be found in these three sections of the project. Our approach will be to challenge these provisional conclusions in the hope that they are strengthened or transformed. Ultimately they will be used to determine scientific knowledge of how digital scores stimulate new creative opportunities and experiences within a range of music practices, and to build a scientific study of inclusive digital musicianship through the transformative potential of the digital score.

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