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Article (Accepted Version)

Hughes, Ed, Eldridge, Alice and Kiefer, Chris (2020) Synchponia: understanding the value of participatory design in developing music technology to support musical ensembles that use notation. *Journal of Music, Technology and Education*, 13 (1). pp. 57-77. ISSN 1752-7066

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Synchonia: Understanding the Value of Participatory Design in Developing Music Technology to Support Musical Ensembles that use Notation

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Alice Eldridge is a musician and Lecturer in Music Technology working at the interstices of music, technology & ecology. She is recognised internationally for her contributions to both new music research and the emerging science of ecoacoustics. As a soundscape ecologist she has featured on BBC TV Spring Watch and BBC radio 4 Costing the Earth; as a cellist she has made numerous appearances on BBC radio 3 Late Junction and Jazz on 3; her contemporary chamber compositions have been broadcast on BBC 6 Freak Zone; and she has appeared on BBC radio 1 John Peel show as a pop bassist.

Chris Kiefer is a computer-musician, musical instrument designer and Lecturer in Music Technology at the University of Sussex. He performs with custom-made instruments including malleable foam interfaces, touch screen software, interactive sculptures. As a live-coder he performs under the name 'Luuma'. Most recently he has been playing an augmented self-resonating cello as half of improv-duo Feedback Cell, and with feedback-drone-quartet 'Brain Dead Ensemble'. His research specialises in musician-computer interaction, physical computing, machine learning and complex systems.

Abstract

The benefits of ensemble performance are well recognised; notation supports group performance, but cuts in music education and changing musical cultures mean that notation is increasingly perceived as a barrier to entry. In an extended participatory design project, we co-designed and developed a software system for networked notation called *Syncphonia* with the aim of enhancing access to and experience of notation-based ensemble performance. In previous work our formal evaluation and informal observations and feedback revealed a wide range of benefits. In this article we are concerned with articulating the knowledge generated and insights gained through this extended participatory design process. In order to do so, we employ a framework for systematic reflection which has been designed to support investigation into the tacit knowledge generated in participatory design. Through this method we focus inward and share three insights into the value of networked notation in contemporary musical cultures; we also look outward and articulate five approaches to participatory design with musical ensembles that might benefit others adopting this rich research method. A pluralistic and inclusive vision of notation is espoused and speculation submitted that a dynamic, networked notation might ameliorate the boundaries between composing, improvising and performing to the benefit of all three.

(**Keywords.** Ensemble Performance, Musical Experience, Participatory Design, Networked Notation)

1. Introduction

Syncphonia originated in an AHRC research project to investigate the potential for networked technology to enhance the experience of notation-based ensemble performance for very young musicians (Hughes 2015). It was co-created through an extended participatory design (PD) process; The first phase consisted of 6 weeks intense development with a primary school ensemble; over the following two years it was workshopped with four ensembles in a wide range of musical contexts including community, youth and professional music contexts and instrumental, choral, classical, baroque and rock music. It is now available for free download for iOS tablets (Hughes 2015).

Syncphonia draws on several threads in music technology research: advances in notational practices supported by new technologies, new concepts of ensemble music, and pedagogical research on mobile and networked technology in support of traditional music education.

Syncphonia's novel technological solution is the use of bespoke MusicXML rendering, synchronised via bluetooth wireless technology (Eldridge, Kiefer and Hughes 2016), thus distinguishing the software from PDF notation formats. Contemporary use of notation in research and artistic practice bears examples of the use of mobile devices to display and synchronise notation, and the use of graphics and annotation to enhance or replace traditional notations. For example, Hope, Wyatt and Thorpe (2018) use networked graphical notation on multiple tablets to support an Operatic ensemble, and James et. al (2017) review the varied softwares that support networked notation, *Syncphonia* draws on this vein of research, by augmenting and synchronising traditional notation across tablets: to support an Operatic ensemble, and James et. al (2017) review the varied softwares that support networked notation. *Syncphonia* draws on this vein of research by augmenting and synchronising traditional notation across tablets.

Musical ensembles are evolving with the support of technology; laptop orchestras currently provide a platform for experimentation and research in this area (Trueman 2017), including evaluation of the efficacy of tablets as ensemble instruments (Riley 2018). While laptop orchestras demonstrate the use of digital instruments and networked computer for performance, there is little work on the support or augmentation of traditional musical ensembles and orchestras with digital technology. Rofe et. al (2017) explore telematic streaming between ensembles, sharing a similar ethos to *Syncphonia* by aiming to use technology to extend participation in ensemble music. Barriers to participation are further explored by Williams (2012), who demonstrates that lack of experience in standard notation prevents participation in traditional music in US schools, although the same students were excelling musically in other areas that did not require this skill. Ng and Nesi (2008) also look at technology supporting traditional music, focusing more on single players, and multimedia enhanced instrumental tuition. To the best of our knowledge, the *Syncphonia* project is unique in its aim to augment notation in the support of traditional musical ensembles, through the development of new software for networked tablets. As such, it has required new approaches in design methodology and research methodology

During our first funded research period, in which we worked with a study group of school children aged 9-11. A thematic analysis (Hanrahan et al 2018) revealed that participants felt an enhanced sense of enjoyment and belonging; they also reported feeling an enhanced better 'sound' due to stress reduction and the ability to read longer and more complex pieces, leading

to an enhanced sense of the structure and flow of the music (Hanrahan et al 2018). Since the first trial, the usage of the App has broadened considerably beyond primary schools and continues to grow. In order to better understand the potential benefits of the App's affordances in wider musical contexts we conducted a range of workshops in diverse musical settings, and continued development in a form of extended PD.

In this article we systematically reflect on the extended PD process through which *Syncphonia* was created, with the aim of articulating the knowledge generated throughout this long-term research project. To do so we adopt a methodology developed in human-computer studies which is presented as a set of 'tools-to-think-with' (Frauenberger et al 2015). This comprises four 'lenses' which scaffold reflection on the nature of the Participatory Design effort: Epistemology, Values, Stakeholders and Outcomes. The tool explicitly accommodates post hoc analysis, to consider the accountability and rigour of the PD process and facilitate transfer of knowledge. (Frauenberger et al 2015).

As our reflections pass through these lenses, we argue that their complementary and intertwined nature support the idea that the overall approach has coherence as well as offering some insights into the experience of ensemble music making witnessed through this technology project. We think this is in part because engagement between novel technology and musical practice with a tradition can surface unwritten rules around how we interact and engage with one another as musicians performing together in different ways using notation. A broader result of this work is therefore to articulate those principles and practices and make the experience of ensemble music making more accessible.

Section 2 describes the original motivation for the project, the methodology of the original participatory design process and reflective analysis methodology used in this paper; Section 3 details our extended participatory design process: a long term initial case study in a primary school and four further workshops in wider musical contexts; in section 4 we use Frauenberger's (2015) four lenses to systematically reflect upon a range of qualitative data collected during these sessions; Section 5 these reflections are distilled and articulated as insights, looking both inward, to the role of notation in ensemble performance and outward to the design process. Finally in section 6 we speculate on the role of technologized notation in future music making.

2. Motivations and Methods

Many UK schools run activities for pupils in which ensembles or small orchestras of mixed instruments play notated music together. Beside pedagogic value, ensemble performance is socially beneficial as well as musically rewarding. Hallam (2010) reports that it ‘promotes friendships with like-minded people; self-confidence; social skills; social networking; a sense of belonging; team work; self-discipline; a sense of accomplishment; co-operation; responsibility; commitment; mutual support; bonding to meet group goals; increased concentration and provides an outlet for relaxation’. However, we know that beginner musicians experience anxiety when they lose their place in the music and attrition rates can go up. In music psychology research, perceived capability, and the psychological need for competence are found to be factors associated with task persistence and enjoyment across many domains.

Staff notation is perceived as challenging by pupils and many teachers, even those with some instrumental training. Further, we know from research that ensemble music-making is a complex activity, involving a range of skills and coordination (Goodman 2002; 153). On the one hand, this is why ensemble music is valuable, because the engagement builds special benefits. Conversely, these are reasons why it may appear difficult or excluding and even stressful for those new to ensemble performance, all of which may lead to decisions to cease playing.

The compositions performed in schools are often simplified arrangements extracted from well-known classical compositions, popular musicals, or pop songs. Flexible or open scores (with flexible parts for transposed instruments and parts differentiated by difficulty) are a feature of such arrangements. However, staff or traditional notation is the norm and many music publishers, including small independent publishers, and larger publishers, sell these arrangements.

In the UK pupils are also expected to perform music together as part of their classroom music experience. Indeed, the national curriculum for music requires that all school pupils at key stage 2 (years 3 to 6, ages 7 to 11) should ‘create and compose music on their own and with others ... play and perform in solo and ensemble contexts ... use and understand staff and other musical notations’ (UK Department of Education 2018). Funding and priorities for music in education are under pressure in the UK. At the same time, ministers have called for the

restoration of music literacy amongst pupils in primary schools (e.g. Gibb 2019). These competing factors mean that creative thinking is needed: the potential for technological innovation is well recognised, but designing tools that genuinely support and enrich, rather than patronise and exacerbate users is an eternal issue.

2.1 Participatory Design: Co-constructing epistemic artefacts

PD (Spinuzzi, 2005) is a method for design and research that is carried out with, rather than for, users. The intended outcomes of this involvement are twofold: (a) to design an artefact that directly responds to the needs of users and (b) to empower users in the design of technology in which they are stakeholders. PD can be characterised as a ‘research through design’ (Gaver 2012) process in which the response to a research question is the co-creation of an artefact between a research team and the users of the artefact, it is therefore ideally suited to the creation of software tools that meet the needs of young musicians. The PD process is an iterative exploration of the research problem through which an artefact is developed and evolved as a possible solution. This process not only results in the development of the artefact, but can also lead to a deeper understanding of the research area, by surfacing the tacit knowledge of the users in interaction with the design and technical expertise of the research team. The artefact embodies the ‘myriad choices’ (Gaver 2012) made during the design process by all stakeholders, and as such, the knowledge gained from the research process is embedded in the artefact. Participatory design is intrinsically context dependent and typically focuses on one user group. However, we were interested in the degree to which our App was beneficial in wider musical contexts; to this end we undertook what we describe as extended PD, a process that took us beyond the original case study to engagement with stakeholders from a range of musical ensembles over several years. These engagements all had bearings on the development of the artefact.

At best the PD process creates rich epistemic artefacts that ‘solve’ the initial problem. Our formal (Hanrahan et al 2018) and informal observations and testimonials suggest that *Synchonia* indeed succeeds in enhancing access to and experience of notation-based ensemble performance. PD is also a form of tacit research process that deepens our knowledge of the area, and it these surfacing the insights that is the focus of this paper. The embedded nature of the knowledge generated through PD makes it hard to evaluate and articulate: in contrast to results in the traditional sciences, PD processes and outcomes do not typically lend themselves to being quantified, compared, generalised or replicated. The insights gained from this research

are entangled with the software, meaning that it is hard to evaluate the rigour of the process, or articulate the lessons learned.

2.2 Analysis of Participatory Design: Deconstructing Epistemic Artefacts.

In order to unpack the process and outcomes, we adopt a conceptual framework developed by Frauenberger et al (2015). The philosophy that underpins PD is deeply rooted in the postmodern tradition, including phenomenology and Marxism. It is supported by fuzzy data and draws seemingly arbitrary conclusions (Frauenberger et al 2015: 94) when compared with positivistic frameworks. The real-world results are testimony to the success of PD as a design method, but the details of are often hard to articulate. In order to reify the rigour, explain the insights, decisions and judgements and to share contributions, four lenses through which to reflect upon the process and products of PD are presented. The lenses are constructed through sets of questions around the following domains: **Epistemology:** *What kinds of knowledge are constructed?* (social, design, methodological and theoretical). **Values,** refer to ideas or qualities that are considered important and worthwhile. These are inherently tied to interests and desires of human beings in their cultural milieu (Friedman et al 2008): *Which values drive the process, explicitly or implicitly? What are the conflicts and dilemmas arising from values? How do values change in the process? How are values reflected in design decisions?* **Outcomes:** *What are the different interpretations of outcomes? Who owns outcomes? How sustainable are outcomes?* **Stakeholders:** *Who are the stakeholders and who participates? What is the nature of their participation? How do stakeholders and participants benefit? What happens when the project ends? What happens when the project ends?*

These lenses were designed for use in both planning and post-hoc analysis. As such the material for reflection is not specified. Being rooted in phenomenology, PD methodologies foreground personal experience. We further recognise the value of a range of data collected during the PD processes as a source of objective information. The data on which we reflected therefore includes a mix of personal notes, technical data and user feedback:

- i. Notes from PD sessions. Each researcher kept individual notes in the project management system for the first six weeks of PD sessions and then four subsequent workshops (2500 words in total).
- ii. Source code and repository issues and commit messages. During the development process code versioning was managed in a Github repository. This platform supports software version control and provides tools for logging issues and updates. These are

- designed to support distributed team working; we co-opted them as a means to track changes in the code base (software artefact) in response to stakeholder feedback (25 issues raised, 257 commit messages).
- iii. Interviews with case study participants: 37 participant interviews of various lengths, 72 minutes in total.
 - iv. Statements from ensemble leaders and players; written statements/responses from 79 participants and 7 leaders.
 - v. Supporting video evidence of performances using the system; (six 30 minute videos plus one for each of the four workshops; over 7 hours in total)
 - vi. Reflection on our own experience as designers.

The reflective process was structured as follows: Each author independently revisited each of the data sets (i-vi), and made detailed notes on the starter questions for each lens. Through a process of reflective discussion, individuals notes were integrated and the degree to which the lenses could be differentiated was discussed, leading to reflection on the coherence of the PD process. These discussions also led to insights around the role of notation in these varying circumstances.

3 Extended Participatory Design Process

3.1 School Orchestra Club

The original case study began in late 2015, when we observed a school orchestra club, composed of 28 pupils aged 9 to 11, in a primary school in East Sussex, UK. The orchestra was organised and directed by an experienced classroom teacher, phase leader for year 5 and 6, with a general (non-specialist) teaching portfolio but having long-standing interests in children's music-making. Rehearsals in normal conditions were characterised by frequent stops because some children got lost and needed help from their teacher or from a parent volunteer. Broadly, it appeared that those children who were able to keep their performing in time with others and not lose their place enjoyed the experience. These more confident students typically had more ensemble experience as well as instrumental lessons. In stark contrast less confident pupils sometimes became visibly upset when they lost their place in the music. The original motivation to build *Synchonia* was to ameliorate this stress using readily available technology. Our principle research question was: *Could a networked dynamic scoring system be transformative to the experience of musical ensemble playing?*

3.1.1 Technical Outline of the *Syncphonia* Apps.

The *Syncphonia* software comprises two Apps (Conductor and Performer) which are synchronised via a bluetooth network. The Conductor presents a full ensemble score (see figure 1) and controls multiple instances of the slave Performer application, which displays the instrumental part of each player's choice. The ensemble leader can set a fixed tempo, or interactively provide a tap tempo at which the parts are updated and synchronise. The bar and optionally beat are highlighted, helping players to keep their place. The Conductor app can run in automatic mode at a fixed tempo, which is useful for reading through new repertoire, or can be controlled expressively, beat by beat, by tapping on the screen or use of a foot pedal.

[FIGURE 1 AROUND HERE]

Figure 1: A screen shot of the *Syncphonia* Conductor application. The full score is displayed, the current bar is highlighted and one bar look ahead is shown in fainter text. The conductor can choose between a set tempo, or interactively set the tempo by tapping on the screen with a two bar count in. From left to right, the controls along the bottom of the page are: Jump to a selected figure or bar; display the current beat, restart at the first bar of the current score, open score manager and open settings. This score shows coloured notes which support those with little or no knowledge of score reading in performing, when used in conjunction with colour coded tuned percussion.

Scores are imported using the industry standard MusicXML format, ensuring compatibility with modern notation software and online archives. Notation is rendered by our own lightweight rendering engine written in OpenFrameworks (Lieberman 2020) using Adobe's Sonata font.

The Conductor and Performer applications are synchronised using Bluetooth 4 networking protocol. This is chosen over WiFi for simplicity and accessibility: No configuration is required and it obviates reliance on institutional networking systems or additional routing equipment. Synchronisation data is multicast to all local devices through the advertising data block. By sharing data in this way, there is no need to create a formal connection between devices, and the system can thereby exceed the connection limit of 12 devices on the iOS Bluetooth stack. Further to this, messages can be transmitted at a high frequency, every 1-2ms, compared to the 20ms minimum for Bluetooth characteristic notifications in iOS.

The initial PD process was carried out over an intensive six-week period (January to February 2016). Each week we brought prototypes of the App to the orchestra club early morning

rehearsal; we filmed the sessions, carried out formal and informal interviews. Immediately after each session we met as a team to reflect on the experience and decide the next round of modifications. In this way we ensured that incremental design decisions were based on user-needs rather than our preconceptions. As an example, in our notes following the first session on 14 Jan 2016 we documented a request for an audible pulse to assist synchronisation (which was added, and then abandoned because it proved to be too intrusive). Our notes show consideration of different possible approaches to the problem of page turning (looking ahead to the next bar beyond the current displayed view). Various approaches to counting in were also tried. We discussed level of detail in terms of visual display of position in the music - and in response to feedback offered the option of toggling between full bar and beat highlighting. Participants pointed out that being able to jump to and pick up (start) from rehearsal figures and/or bar numbers easily and quickly would help efficiency and reduce waiting times in rehearsals. A consistent and clear page view for the conductor was gradually developed (Figure 1).

A research fellow, focused on the psychological benefits to pupils of the technology, was embedded into the original six-week case study as a member of the team. Findings were that greatest benefit applied to those already enjoying playing orchestra, but with less perceived ability. By ‘reducing barriers to engagement, including keeping time and synchrony’ (Hanrahan et al 2018: 28) the technology helped to increase enjoyment and perceived ability in those pupils, leading to a higher likelihood sustained engagement and reduction of attrition rate.

Following the initial PD process we realised that researchers’ and subjects’ active participation in design and iterative feedback raised new questions, pointing to further developmental and experimental potential beyond the scope of the original users: *could a networked notation system engage and benefit non-classical users; could simplified or reduced scores promote creativity and structured improvisation while being supported by a networked notation system in mixed ensemble settings?; does a networked notation system promote a broader understanding of musical structure in ensemble music-making?; could colours and other affordances of tablets help non-readers take part and acquire a taste for musical notation?; could a networked notation system benefit adult choirs with mixed reading skills?; is there value for more experienced users playing longer and more complex scores?*

3.2 Rapid PD in mixed-experience ensembles

We took these questions forward to workshop them in a number of diverse and informal contexts. In this section we describe the key musical features of these workshops, and report illustrative feedback. These musical ensembles were selected as illustrative but by no means exhaustive examples of contemporary music practice.

Workshop 1. BIMM (British and Irish Modern Music Institute, Brighton) - 22 January 2016
This event explored notations in a mixed session combining five classical players (flute, clarinet, violin, cello, piano) with four piece band (two guitars, bass and drums). In this specially convened workshop, the researchers worked with members of *Orchestra of Sound and Light* and a rock band at the BIMM Institute Brighton. Approaches to two pieces were explored. Both pieces featured adapted and/or reduced networked notations via *Syncphonia*. It was found that these invited exploration of the realm between composition and improvisation.

We worked on two pieces: (1) an adaptation of Holst's *Mars* from *The Planets* (1914-1916); and (2) a composition by Ed Hughes called *Alice in Wonderland* (2016). Special arrangements of both pieces featured parts with simplified or reduced lines. In addition to enabling improvisation and flexibility within a given long-form structured composition, participants reported that the system significantly reduced or removed their anxieties around notation, particularly in Hughes's composition:

'I haven't done a reading gig in a really long time. I don't do much reading, especially sight reading. It was just happening' (Guitarist 1)

Workshop 2. Contemporary Music for All - 21 February 2016

In this Brighton Science Festival workshop, members of experimental classical ensemble *Contemporary Music for All* Brighton used the software to perform works by Grieg and Hughes. Members of the public also participated in the event, without requiring prior musical reading experience. Thus, experienced readers mixed with less experienced musicians and with non-readers.

The App's conceptual simplicity leads to open-ended application. Whereas in workshop 1 reduced notation enabled a cross-over band to perform together, in workshop 2 the ability of the iPad to display colour was used to enhance the supportive function of notation in a creative

performance setting. First, a very simple diatonic part was added to the existing score by Hughes and labelled ‘colour notes’. Then the Boomwhacker® colour system was applied to the note heads in the colour notes part. Noteheads then appeared in colour when the Colour Notes part was selected on a performer’s tablet.

Hand percussion in Boomwhacker® colours were provided to participants. Video documentation (Hughes 2016) shows that very young participants as well as adult participants were able to coordinate use of bells and chimes to the display and thus gain an experience of ensemble music-making which would not otherwise be possible. Workshop feedback (Hughes 2016) demonstrated the value of the App in supporting the socially cohesive aims of the performance culture espoused by CoMA, a value this group holds alongside the exploration of contemporary work. It brought together performers with a wide range of abilities involving everyone and moving the focus towards participation and away from the specialist performer/audience divide. It brought together performers with a wide range of abilities involving everyone and moving the focus towards participation and away from the specialist performer/audience divide.

Workshop 3. Brighton Early Music Festival - 18 February 2017

In this Brighton Science Festival workshop, members of the Brighton Early Music Festival Community Choir performed early music scores in part notation. For this, the software was extended to display lyrics. The music performed was all polyphonic, and was selected by the Brighton Early Music Festival’s artistic director, Deborah Roberts:

Thomas Tallis: *If Ye Love Me*

Giovanni Pierluigi da Palestrina: *Sicut servus desiderat*

Orlando di Lasso: *Super flumina Babylonis*

Once again, this was a mixed ensemble with a range of singing experiences and skills. Several singers were accomplished sight readers. Alongside these were community singers with very restricted musical literacy skills. The community singers tended to rate the intervention more highly than the experienced singers. However, participants from both groups pointed towards the value in terms of heightening the perception of rhythm within the overall structure of the work, commenting that the app ‘*Helped with rhythm, length of long notes, and rests*’. Another singer pointed out the value of the App in particular for navigating renaissance polyphonic music: ‘*The particular benefit is music which is polyphonic and not block harmony*’.

The software then showed parts only on the Performer App, synchronised to the score view which appears only on the (single) Conductor App. As a result, singers could only see their own part, whereas normal practice for singers is to be able to see the whole score. This caused some discussion, and issues such as cueing and listening were felt to be particularly acute for singers in ensembles; this discussion was a factor in the software being later extended to include a score view also in the Performer. However, at the workshop, some participants pointed out a connection to the much earlier practice of singing from part books. It was further observed that (shared bodily) tapping to keep pulse within a vocal ensemble is a feature documented in paintings from the period in which madrigals were written, a practice now forgotten but recorded in visual artⁱ. Again, the emerging technology, through the process of PD, and in its very design, gently interrogates customary musical performance practices and shifts the focus of discourse towards consideration of the social and the participatory.

Workshop 4. Brighton and Hove Youth Philharmonia - 5 June 2017

We were invited to workshop the App in a rehearsal of the Brighton and Hove Youth Philharmonia, conducted by musician and film composer Peter Davison. In one sense this was a return to a conventional musical ensemble format. On the other hand, it was the most ambitious trial of the App to date in two ways: because we successfully expanded the number of synchronised tablets sharing the Bluetooth network to 25; and because we undertook to implement the entire score of the overture to *Così fan tutte* (1790) by Mozart into *Syncphonia*.

For this occasion, the team adapted the *Conductor* App to respond to signals from a MIDI floor pedal. This enabled the conductor to set and to some extent to adjust, tempo while keeping hands free for expressive direction. Video documentation (Hughes 2017) shows the conductor able to work the App successfully while retaining the ability to make gestures with hands and arms to signal expression to the orchestra, such as *crescendo*, emphasis, accent, articulation and phrasing.

Feedback was divided. Some members of the orchestra commented positively on the support that the App offered. Interestingly, many added that the novelty of the technology was a positive factor in increasing interest and engagement.

'Didn't have to turn pages...Helps you to keep the beat...The kids are absorbed to tech...it was great to do something different'

'[Benefits included] having a clear sense of time and 'togetherness'; music easier to play together; much more involving'

Some users were more sceptical of the technology.

'It's easier to follow the music...it is harder to follow the conductor on the iPads'

'Who do you follow the conductor or the iPad?'

Conductor Peter Davison added that the technology helped to focus and motivate the musicians in rehearsal, and that it would benefit sight reading and therefore help young people assimilate the bigger picture of the music's style, form and structure more quickly: *'They were very responsive...they were quiet, they were engaged...it's really good especially when you are sight reading...you don't need the teachers to go round pointing stuff out'*.

4. Analysis: Reflections on the design process through four lenses.

The four lenses proposed by Frauenberger et. al. (2015) are suggested as a 'tool-to-think' with; they offer the framework as a tool for post hoc analysis, to investigate trustworthiness and facilitate transfer of knowledge. *Trustworthiness* is presented as a measure of quality and rigour, as an alternative to positivistic validity and generalisability. It is seen to stem from four distinct properties: credibility, transferability, dependability and confirmability (Guba 1981).

The first lens is *epistemology*. All of the research team are musicians with plenty of experience of ensemble music. However, our PD process gave us new understandings of *social* aspects, customs and practices of orchestras and ensembles beyond our own experiences. In some cases it highlighted the role of the musical director as the key gatekeeper, and revealed anxieties amongst the other ensemble members: about losing their place in the notation, about their value as part of the ensemble, and about how well the ensemble as a whole was playing together, the latter becoming apparent towards the end of the process when the musicians commented on how the orchestra was sounding much better with the App in use.

In terms of *design knowledge*, we gained a better understanding of individual preferences in key features in the system, for example methods for page turning and score viewing. Due to the very tight constraints of our PD process we rapidly came to appreciate the importance of simplicity and reliability in design when working with orchestras and ensembles, which was echoed in the new understandings we gained in methodology. We worked with the case studies

during their live rehearsals and workshops. We needed to fit our PD process into the flow of their rehearsals, with minimum risk of disruption. In retrospect we felt that these constraints led to a better-quality design, although we also realise that these constraints may have limited generalisability to wider use as they limited our ability to explore some more complex features such as score annotation.

The constraints meant that we could only add features that would be quickly and intuitively understandable for the conductor and orchestra, and forced us to carry out ‘extreme testing’ before each PD session. This was entangled with maintenance of trust between the research team and orchestra; to reach a good design and obtain quality feedback, we needed them to trust the technology, and trust us as new participants in their rehearsals. We evolved various methods for eliciting feedback from the orchestra with minimum disruptions to their process, including quick interviews following rehearsals and workshops, conversations with the conductor after the rehearsal, brief conversations with participants while we helped them during the rehearsal, conversations with parent helpers, extensive note taking during the PD session and group analysis of these notes directly following each session. We learned to look for very clear markers of the effect of the system, for example the first time the orchestra or ensemble played through a new piece with the support of the software, or the first time that the conductor was able to leave the conductor’s stand and help the children while the software guided them through the notation.

Another form of knowledge relates to the *theories* constructed through PD. Our research was guided by the hypotheses that showing musicians their place in musical notation would (a) reduce stress and enhance the experience of playing in a musical ensemble and (b) lower the barriers for entry into notated ensemble music. From these hypotheses, several sub-questions arose: *can an orchestra play to a click track or to graphical time cues? How should automatic page-turning work on a digital system? Can a conductor attend to software while conducting? Can networked software act as a mediator for entrainment between musicians and conductor and score?* These questions were translated into design features, and tested and explored through their use in the orchestra; thus, the knowledge generated through the testing of these theories is tightly entangled in the design artefact resulting from the PD process. We feel that the PD process assured credibility of this knowledge in a self-generating manner; without credible answers to these questions embodied in the system, we would not have seen clear

success markers from the school orchestra, and from the ensembles who have used the system following this initial process.

Participants in the BIMM workshop, which brought together a rock band with a classical ensemble, reported that the networked notation experience could reduce stress, relax the player in the group setting to give confidence to produce a higher level of musical expression and lead to more complex improvisation in a long form compositional setting. Thus, reduced notation can be an asset in a group setting, especially one in which pulse is unifying across genres. This is affirmative of the value of a versatile notation made newly dynamic through digital and networked means, and the affordances of technology in today's evolving and blended musical contexts.

The Brighton and Hove Youth Philharmonia (youth orchestra) session showed us that metronomic pulse and beat coordination are complex and subtle matters especially in an orchestra where the 'rules' of performance and interaction are learnt through practice over weeks and months, and not explicitly stated or written down. The technology prompted participants to articulate this knowledge, that musicians' musicality, at least in certain contexts, depends on not being tied to a metronomic beat: "*You can't do tempo rubato, it's really hard to do ralls.*" (secondary school participant). This led to a decision to offer entirely manual (touch) led beat-following - the main score would be moved along by the human musician not the machine.

The second lens is *values*. In the Frauenberger framework this refers to ideas or qualities that are considered by the group as important and worthwhile; shared beliefs and concerns that inform the interests and desires of human beings in a cultural setting. As such all our stakeholders engaged in leading and following, and assigning of roles, and we considered this to demonstrate implicit subscription to the idea of an individual performing in a collective - giving up to some degree personal identity in service to a larger common ideal which brings rewards of well-being through shared musical expression.

Our stakeholders implicitly subscribed to the principle that it is socially useful to extend the benefits of ensemble music-making with notation to a wider range of people. This is likely to be because the research team's own values reflect belief in the importance of ensemble music making for the many, and so our software inscribes values around accessibility into its design,

and therefore fits best in such contexts. Although performing music with notation can be excluding to those without music literacy, their lives amongst all these projects a counter-veiling desire to make access to music literacy seem easier to attain with rather than without technology, and indeed to make such experiences productive and empowering.

In the case of the primary school orchestra, paper music parts being used already provided options in terms of levels of difficulty which were distributed by the orchestra's adult teacher based on her knowledge of individual abilities and empirical understanding that frustration in ensemble music making leads to higher attrition rates. As has been noted, the project sought to extend the concept of accessibility by using some additional affordances of technology, including colour. The orchestra could use the digital parts like paper - because they mapped to paper as closely as possible; and yet individuals could choose their preferred part according to both self-perceived ability and progress - toggling via the menu between, say, the more challenging melodic 'violin 1', and the more accompanimental 'easy violin'.

In the case of the choir workshop, we found that although our participant singers liked to be in service to the larger experience of the music (polyphonic choral music), they also liked to perceive the ensemble visually - in score form. This is partly for practical reasons such as cueing from other parts. However, some singers reported a desire to be able to view the whole piece. The balance between the individual and the collective that is so characteristic of ensemble music is thus inscribed as a value into the very practices of choral singing with notation and the structures of layout, typesetting and formatting of the notation that mediates musical performance. This workshop's critical engagement with the technology also led to reflections on the tension between the need for coordination and synchrony in the form of regular pulse, and the way in which phrasing and expression cause drifts away and returns to that governing beat. Music may be governed by pulse, but it should not be 'mechanical' or, at least, it should encompass the possibility of resisting perceptions of the mechanical in favour of perceptions of human expressivity.

In a similar way, in the case of the youth orchestra workshop, several participants expressed the feeling that the human experience of musicmaking should not be displaced by a machine. On the one hand participants perceived value in the App to scaffold and enable more rapid and synoptic appreciation of longer works, leading to more successful 'run throughs' more quickly. They commented positively on this. But they were also concerned about a potential depletion

of human musicality. Interestingly, one participant perceived it as a threat to traditional practice. “*It takes away the conductor’s purpose and you need to have the conductor’s purpose*”.

However, in the case of the BIMM workshop, which brought together a five-piece classical ensemble and a rock band of three guitars and drums, we discovered unexpected connections being mediated by the software in ways that seemed fruitful and transformative. The underpinning pulse/tap approach to the design of the software mapped on to the shared language of the two very different ensembles. Both groups enjoyed exploring music (Hughes and Holst, the latter in fact having some track-record as a subject for experimental progressive rock tracks in 5/4) in which driving rhythms and ostinatos were modulated by gradually changing harmonies and often delicate approaches to timbre and instrumentation. So, although superficially the two bands were worlds apart, the sensitivities of all nine musicians yielded a remarkable blend, and shared understanding of musical intensity in timbre, harmony and dramatic contrast. Through the workshop, benefits were acknowledged in two directions. For the classical musicians, the reduced notation and visual synchrony created more space for improvisation than they normally experienced. For the rock musicians, the reduced notation and visual synchrony reduced the worry of getting lost. Both bands found the software transformative but also speculated that the software could be good as a scaffold but could risk becoming dependent. The role of the software might be to scaffold new skills acquisition, question existing models/practices by modelling/mediating them through tech and reflecting back and to gradually efface itself again.

The third lens is *stakeholders*. PD grew from labour contexts where workers and management and employees and employers are the primary stakeholders in any PD project. In our cases, these are the ensemble leaders, and the players. Together with the research team in their mediating and facilitating roles these account for the three principle camps. Our team comprised the researchers, two other programmers, and a partnerships manager. The mediating role is not purely altruistic. We recognise the impact of successful research on grant income and academic status. As with many PD design projects, beyond the immediate team interest groups may include wider educational and cultural communities and government policy makers (Gilund 2012). With respect to our project we might consider all members of musical communities as potential stakeholders. These considerations were folded in via a carefully selected steering group with whom we openly shared reflection and developments throughout

the project. Gärtner and Wagner (1996) have proposed actor network theory (e.g. Latour 2013) as a useful tool for analysing the structural relationships in PD projects. Musical ensembles in general and music ensembles in PD in particular can be usefully conceived of as a network of actors, enabling reflection of not only the power relationships between players and conductors, but the active roles musical notation plays in mediating these relationships. How does *active* and dynamic notation mediate differently? And how does this affect players' experiences?

In the BIMM workshop, participants expressed pleasure at the higher level of creative improvisation that the system afforded – the system facilitated complex communication and expression. 'My biggest fear was I was going to lose my place... but in the improv parts I was able to focus on how I phrased, and dynamics'. There was a consensus amongst the classical and the rock musicians that the technology enabled a rapid overview of the structure of the piece and by implication the rapid development of a shared language across styles, and yet that it would usefully efface itself once it had fulfilled its purpose and function. 'Getting through the whole tune is paramount'.

At base our project was a design problem. Design decision making is the exercising of power. This is a central insight of PD (Bratteig and Wagner 2012). We were cognisant of the need to set aside our assumptions over how best to make design decision – from the ways in which notation was rendered to interface design for performers and conductors, sonification and visualisation of tempo. In all cases the gatekeeper's trust was crucial, not only in initial introductions, but also in being literally in charge of rehearsals. Where an individual conductor or director led the session, their influence is felt not only rhythmically, but in their mood, emotion and attitude which set the tone of every rehearsal. At the same time, our primary concern was the players' *experience*. We needed therefore to both negotiate this power relationship sensitively, and to make our values, assumptions and preconceptions as transparent as possible. On reflection our emergent methodology was successful in this regard. Following in session note-taking and discussion (see above), we logged requests as issues in our private Git repository. It provides functionality to flag errors or make requests, as well as messages associated with each new code update (issued as an argument to the command *commit*). We repurposed this system as a form of session feedback to the programmers, who often worked remotely in time and space. They worked to resolve issues, and flagged the solutions in Git commit messages. This simple method assisted the development pathway, and allowed us to trace the origins of software features to particular players in particular ensembles but matching

in session notes, to Git issues and commit messages. The software development methodology reified an emergent principle or maxim: “*every voice is heard*”.

The fourth and final lens is *outcomes*. Assessing the outcomes with respect to the impact participation has made is the most important way to justify participatory approaches (Frauenberger et al 2015: 102). As above, our principle concern was the *experience* of our primary stakeholders, the ensemble musicians themselves. As enhancement of our primary stakeholders’ musical experience was the key desired *outcome*, we necessarily reflect on the two together.

Our primary concrete output was of course *Syncphonia*, the software App suite and its portfolio of specially prepared compositions, which is now publicly shared with communities worldwide. Whilst we might assume our primary stakeholders have a vested interest in musical experience of widest communities, we were specifically concerned with the impact of *removing* the technology from the school sessions at the end of the trial (phase 2 sessions were typically one-off, so there was a clearer understanding of commitment and benefit from participants).

In the school group, because what we came to dub the ‘iPad effect’ (an enhanced attention, interest and obedience) was strong, there was a social concern that returning to paper scores might create a sense of loss. However, the responses of the stakeholders when they returned back to paper scores after the initial trial answered some *theoretical* questions we had. In the trial design phase we discussed the possibility that the bar highlighting might act (mediate) either as a crutch or scaffold to musical literacy. A crutch means supporting the children who struggled with reading, but making them reliant on it such that when it was taken away their ability (and experience) was diminished. In contrast, a scaffold would be expected to ameliorate stress, freeing up cognitive resources to allow better concentration, comprehension and development of skills upon which ensemble performance depends: learning of notation to fingering, to pitch associations at the core of musical literacy, listening to others etc. Much like a scaffold protects a young plant to high winds, enabling it to grow the structure necessary to support itself, the scaffold hypothesis predicts a *better* ability to read notation on paper scores. To our surprise and delight this second hypothesis seemed to most accurately reflect the experiences of the school orchestra. An unexpected outcome, that empowered stakeholders in

unanticipated ways, was that some children even commented that they felt that they would be better able to read the paper scores after the experience.

The software acted positively in other unexpected ways. In the BIMM rock-classical group we realised that reduced notation could be valuable not only for those new to music making, but also for expert performers where the reduced notation supported confidence in improvising in classical musicians by keying in score position and overall sense of structure while opening up new windows in time for flexible improvisation. This showed that dynamically synchronised, reduced notation could be an *asset* in more fluid (improvisatory/mixed) performance practices. For the singers in the Brighton Early Music Festival Community Choir, the users reported being able to learn faster, again because of the quality of being able to sing through a whole piece – to arrive at a synoptic understanding of the whole, more quickly – thus mitigating the off-putting frustration of not seeing that big picture soon enough. For the musicians of the youth orchestra (Brighton and Hove Youth Philharmonia) this was an experience that was engaging and fun, because of the sense of contributing to the development of a tool with educational as well as musical value, and one which also prompts and surfaces questions about the nature of musicianship in ensembles itself, unusual in a tradition in which the ‘rules’ and practices are rarely written down.

In our original case study primary school ensemble, students also commented that the orchestra *sounded* better (Hannrahan 2018); again, it was never our aim to improve the ‘quality’ of performance, just the experience. This outcome lent credence to the theory that stress reduces capacity for other core musical acts such as listening to others, intonation and tone. In public sessions, the ‘colour notes’ even enabled those with no musical experience to play along.

5. Discussion

We have reflected on the experience of our PD process through Frauenburger et. al's four lenses. They specify that the concluding reflective step is to consider *coherence*, as the prime indicator of internal rigour. Coherence considers the relationship between the four lenses following guided reflection; the overlap between them and the directions they pull towards. During our reflection process, we often struggled to fit observations into a single one of the four lenses. For example, our focus on design features as testable hypotheses falls into the *epistemology* lens, but is also challenging to separate from *values* of our testing approach, and our relationship with *stakeholders*. Many examples like this reveal leakage and overlap

between the lenses, which we interpret as evidence of balance and coherence across the PD process. A possible source of *incoherence* is the durational aspect of this project, which has compressed and stretched across several years and with many groups of musicians. This created some challenges in our reflective process in summarising factors which have been broadly consistent across the entire period.

Reflecting on the rich PD process through these four lenses reveals insights both inward, on the nature and role of *networked notation* and outward, on understanding the features of our research that might be valuable to future design of technology for ensemble music making and pedagogy.

The value of networked notation

We first focus on the role of networked notation, looking inward to the lessons learned during the PD research process. In the context of our experience, we learned that: *Network notation has the potential to bridge diverse musical praxes*. Dynamic musical notation can mediate relationships between players to make it flatter, less hierarchical and more improvisatory or playful. Dynamic notation provides synchrony, which is both a practical bond and a shared value, and an experience which can connect different genres. *Networked notation can lower the bar of entry to ensemble music*, by reducing stress of losing place in the notation, and by freeing up cognitive capacity. We have observed, with multiple groups, that ensembles can play to an automated timing cue, either an audible click or the visible animation of a moving timestep. This opens up new practical and creative possibilities for machine-led ensemble music. We have seen that *networked notation is potentially valuable at all levels of musical experience*, from primary school novice musicians through to professionals.

PD for ensembles

We also look outward, on the value of participatory design process and the potential uses of this method for other researchers who wish to engage with the uniquely challenging circumstances of participatory design with musical ensembles. Our reflective process highlighted five valuable insights from our approach. (1) *Simplicity, reliability, relevance & trust were key to our design process*. These factors are closely-interlinked in the context of designing with musical ensembles. Simplicity and reliability are conditions for being able to work with musicians at all experience levels within the constraints of a rehearsal. The PD team must gain the trust of the ensemble by listening and responding to fundamental needs and

concerns or all stakeholders, and by establishing working practices that complement those of the ensemble. Following from this, new hypotheses, which are explored in the form of new design features, should maintain relevance to the ensemble's musical practice. Our processes have benefitted from (2) *a rapid, situated design cycle*, characterised by fast feedback, continuous deep reflection, and awareness of clear milestones. This process involves continuous behavioural evaluation, to assess whether design decisions are supporting primary stakeholder needs, evidence for which might be triangulated from various sources, e.g. visual evidence, discussion with stakeholders. During our PD process, we came to be guided by the principle that (3) *every voice should be heard*, although it should also be acknowledged that the voice of gatekeepers may carry more weight, for example in a musical ensemble, the voice of the conductor carries special importance. Our experiences have shown that (4) *new technologies can help to surface values and practices that would otherwise go unspoken*. This may in turn help to demystify ensemble music practice and make it more quickly accessible. Problematic practices and experiences identify with attrition rates and are associated with exclusivity and elitism. Nevertheless, respecting values and traditions is essential to the cultural value and meaning of ensemble music practices. Finally, (5) *new technology can act as a scaffold rather than a crutch*, although care is needed at points of technological intervention and effacement to avoid depleting the best qualities of established ensemble music-making practices.

6. Thoughts on the Future of Notation

While the *Syncphonia* App was conceived as a tablet-based, networked, digital music notation App for primary school ensembles, it seems that it also provokes debate and research insights in a much broader range of settings, including community and youth settings. This is perhaps because its conceptual simplicity leaves space and scope for open-ended adaptations.

In settings involving cross-over combinations of instruments and styles, and particularly where inexperienced or novice participants are playing in ensembles for the first time, *Syncphonia* is rated as strongly supportive and even capable of conferring and broadening access to the pleasure and benefits of ensemble music-making. The App speaks well to issues around music in socially concerned situations where active participation is of primary concern.

Based on rich feedback from a wide range of participants, *Syncphonia* seems to have the capacity to stimulate conversations about the broader social functions of music, especially with

regard to participation, as well as to support practical ensemble music-making. More broadly, and thanks to its development using PD principles which made the *experience* of users its fundamental motivation, the project has the potential to connect adaptively and responsively to concerns and agendas around the value of active participation in ensemble music-making in education and in broader cultural experiences.

These insights, gained from systematically reflecting on the process of designing networked notation to support the experience of ensemble music performance, counteract a cultural tendency to reject musical notation as difficult and accessible only to the few. Rather than abandoning notation-based methods of learning and composing music, plural understandings of notation and composing, especially in groups, are now needed. If music notation became realtime, responsive and collaborative, while drawing on past and present music, how would this change the experience of composing and performing in groups in schools?

Syncphonia shows that through networked technology you can interrogate musical notation's social and cultural relevance to young people in schools and to broader musical communities. In music, plural understandings of notation and composing, especially in groups, are now needed. If music notation became real-time, responsive and collaborative, while drawing on past and present music, how would this change the experience of composing and performing in groups in schools? We think this continuing work might help to make the boundaries between composing, improvising and performing more porous, to the mutual benefit of all three activities.

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ⁱ Images of 16C paintings show singers in close physical proximity, frequently with hands resting on other singers' shoulders. E.g. 'A Concert' - after School of Palma Vecchio, Venice Venetian painting; Niccolò Frangipane Satire on a madrigal concert