Facilitating self-regulation of instrumental practice with digital technology: A framework, a synthesis of literature and a call for research

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Abstract

Instrumental practice is vital to musical development. Between lessons musicians need to employ considerable self-regulated learning strategies to solve learning problems and to manage their practice. Many children lack these self-regulatory skills for effective and independent practice. Digital technology advancements are offering teachers new ways to support music learning and to scaffold self-regulation in classroom settings. This semi-systematic literature review explores scholarly research in these areas to understand the implications for instrumental practice. Firstly, through examining the process and learning factors of instrumental practice, this paper identifies Self-Regulated Learning Theory as an appropriate framework to explore children's development of self-regulation. Secondly, a synthesis of literature reveals the limited extent of research on the use of technology in facilitating this learning context. This paper highlights the fundamental need for further research into the role of technology in supporting students to become more independent learners and effective musicians.

Key words: Digital technology music tools, instrumental music practice, self-regulated learning

Introduction

Instrumental learning in Western culture is traditionally offered via studio teaching utilising a master-apprentice model (Burwell, 2013; Davidson & Jordan, 2007). Between individual or small-group lessons, students are encouraged to develop their musical skills by practising their instruments. This is fundamental to musical instrument expertise development (Hallam et al., 2012; McPherson et al., 2015). As a solitary endeavour, practice requires time, commitment, effort and perseverance over a prolonged period (Ericsson et al., 1993; Lehmann & Jørgensen, 2012). Younger beginners often encounter difficulties and need to overcome many obstacles to learn effectively (McPherson & Zimmerman, 2011). Practice may not be enjoyable and becomes particularly challenging when lacking in effective strategies (Hallam et al., 2012; Pitts et al., 2000). Slow progress, poor musical engagement, distractions and negative parental feedback can lead children to cease instrumental learning (McPherson et al., 2015). Students, particularly younger children, require concrete strategies and appropriate support during practice to enable effective learning and to sustain instrumental learning engagement.

There is no overarching framework to explain the development of instrumental practice skills and knowledge, and musicians' practice approach can vary depending on age and expertise. Advanced adult musicians tend to utilise extensive mental strategies such as problem-identification, goal-setting, selection of appropriate strategies and self-monitoring of progress (Hallam, 1997a; Hatfield

et al., 2017). In contrast, a majority of children in the beginner years lack skills to learn effectively and independently. They are unaware of making errors, are unable to identify and focus on difficult sections, and consistently play musical repertoire from beginning to end without using strategies for improvement (Hallam, 1997a; McPherson & Renwick, 2001). Children who apply more sophisticated learning strategies are more likely to achieve higher musical expertise (Bartolome, 2009; McPherson, 2005). Correspondingly, many studies in instrumental learning investigate how children can cultivate their practice to independently incorporate more advanced strategies.

Between lessons musicians need to employ considerable self-regulatory strategies to solve learning problems and manage their practice, including structuring their learning environment and seeking help and feedback (McPherson & Renwick, 2011). In the learning context, *self-regulation* refers to the process in which learners proactively generate thoughts, feelings and behaviours to attain skills for learning (Zimmerman, 2000). Unlike fixed abilities or character traits, self-regulation is regarded by Bandura (1986) as a social-cognitive construct whereby learners can cultivate self-regulatory skills through interactions between personal, behavioural and environmental processes. Digital technology (DT) advancements have provided new ways to create and structure learning environments. Correspondingly, DT plays a prominent research role into the facilitation of self-regulation during learning (Dabbagh & Kitsantas, 2018; Devolder et al., 2012).

Increased accessibility to new technologies offers innovative opportunities to create, perform and respond to musical experiences (Savage, 2017; Webster, 2015). In music classrooms, DT can support learning that is authentic, relevant and valued by students (Crawford, 2014, 2017; Wise, 2016). Within the highly personalised context of individual instrumental learning, Creech and Gaunt (2012) suggest the potential for pedagogical transformation if instrumental teachers and students fully exploit the possibilities of DT. Given the increasing availability and affordances of new technologies, it is crucial to explore how DT can facilitate children to overcome obstacles and develop skills to self-regulate their instrumental practice.

With increasing reliance on technological platforms for learning, the role of DT in instrumental learning is crucial. This paper reviews the literature and contributes to scholarly research in two ways. Firstly, this research identifies a relevant framework to examine children's self-regulatory skill development within the instrumental practice context. Secondly, through synthesising findings from multiple disciplines (instrumental practice, digital technology and self-regulation in learning), this paper highlights a gap in the literature and offers research recommendations on the facilitation of self-regulated instrumental practice with DT.

Methodology

This study is framed by two research questions. In the context of instrumental practice:

RQ1: What theoretical framework provides an appropriate foundation to explore children's self-regulatory development?

RQ2: What is the extent of research involving the facilitation of children's self-regulatory development with digital technology?

This paper discusses these questions through a semi-systematic review (Snyder, 2019). This approach is intended for topic areas that draw on diverse disciplines and is particularly suitable for mapping a field of research, synthesising the state of knowledge and identifying gaps in research. As a review of all relevant articles was not possible, a search strategy was utilised to retrieve literature relevant to the research questions (Snyder, 2019).

Inclusion criteria for articles include scholarly literature within the intersections of two or more of the following areas: instrumental practice, self-regulation in learning and digital technology. Search keywords include combinations of "music learning", "instrumental practice", "children", "self-

regulat*", "technology" and "digital tools". Search criteria comprise of empirical and theoretical articles in English from peer-reviewed journals, edited books and thesis dissertations. Given the differing rates of publication, literature relating to instrumental practice and self-regulation published between 2000 and 2020, and DT-related articles between 2010 and 2020, were retrieved.

Following the initial search (which yielded 522 articles), abstracts were scanned and articles with lesser relevance to the research context were excluded. Ninety-four articles were selected for further analysis based on their applicability to the research questions (Snyder, 2019). Additional works (e.g. seminal works and commonly-cited articles) were included through the references of various articles. Resulting articles were categorised, summarised and coded according to their topic and themes covered. Thematic analysis was conducted to integrate concepts and abstract ideas (Creswell, 2012; Snyder, 2019). These themes are discussed next, with the purpose of identifying a theoretical framework (RQ1) and ascertaining the extent of scholarly research in the area (RQ2).

Instrumental practice and self-regulatory development: A framework

Nature of instrumental practice

Instrumental practice is conceptualised in varying forms in scholarly literature. Lehmann and Gruber (2006) describe it as a systematic and effortful activity consisting of predictable stages and activities, aimed at establishing strong internal representations of musical works and performance conditions. Alternatively, Barry and Hallam (2002) conceptualise instrumental practice as a multi-faceted activity involving the development of complex cognitive, technical and musical skills. Facets of practice include developing technique, learning new repertoire, developing musical interpretation, memorising pieces and preparing for performance. McPherson et al. (2015, p. 16) describe practice as "encompassing the range of thoughts and behaviours" to engage in developing "internal memory representations necessary to understand and execute a musical task" in order to perform repertoire in a technically-fluent and musically-expressive manner. Considered collectively, instrumental practice is a multi-faceted endeavour and encompasses a range of activities, thoughts and behaviours required for instrumental learning.

Instrumental music research indicates that younger children typically practise differently to adults and older peers. When examining the practice approach of 22 professional musicians (aged 22-60) and 55 novices (aged 6-18), Hallam (1997a) concluded that professional musicians possess extensive mental strategies compared to novice musicians. These professionals showed considerable self-awareness and knowledge of strategies, while 67% of novices consistently played their pieces from beginning to end without stopping to correct errors. Other research supports these findings. In a case study of two advanced conservatoire organ students, Nielsen (1999, 2001) observed extensive use of mental strategies to optimise learning, including strategic planning, goal-setting, self-instruction, monitoring, evaluation and task-related strategies. Contrastingly, McPherson and Renwick (2001) observed children (aged 7-9, n=7) who spent over 90% of practice time playing their pieces once through without incorporating any specific strategies. Students (aged 9-10, n=3) in Pitts et al.'s (2000) study also revealed negligible strategies and did not attempt to identify or correct problems. Comparatively, in research with beginner adults and older (adolescent) children, participants demonstrated more practice strategies and greater self-awareness, although they did not exhibit the extensive knowledge and skills found in expert musicians (Leon-Guerrero, 2008; Rohwer, 2005). Altogether, the novice practice approach has been more commonly observed in younger (primary/elementary school-aged) children.

Research into instrumental practice investigates how individuals can cultivate more effective

practice behaviours. Hallam defines *effective practice* as an activity "which achieves the desired end-product, in as short a time as possible, without interfering negatively with longer-term goals" (1997b, p. 181). Ericsson et al. (1993) refer to this as *deliberate practice*, a highly-structured and goal-oriented activity requiring extensive effort, concentration, time and energy. In their study, expert pianists reported over 10,000 hours of deliberate practice by age 20, compared to 2,000 hours for amateur pianists. The authors conclude that the main difference between expert musicians and others is their life-long commitment to deliberate practice. Sloboda et al. (1996) conceptualise effective practice as *formal practice*, comprising of the improvement of mechanical performance aspects through technical exercises, and mastery of expressive and technical problems in musical repertoire. In a study with 257 students (aged 8-18), the authors found a strong positive relationship between amount of formal practice and musical achievement, suggesting that formal practice is "a direct cause of achievement level rather than merely a correlate of it" (Howe et al., 1998, p. 405).

To explore how children can develop more effective practice behaviours, an examination of the factors and composition of practice as demonstrated by advanced musicians is required. The process and requisites of instrumental practice, as viewed from both detailed and broader perspectives, are considered in turn.

Process of instrumental practice

From a detailed standpoint, an instrumental practice session can be likened to a series of problem-solving activities encountered during learning of repertoire, or while developing technique, automaticity, personal expression and musical interpretation. Problems occur at all expertise levels, although the extent of problem-identification and resolution vary remarkably with age and expertise (Hallam, 1997a; Leon-Guerrero, 2008).

Instrumental practice requires a range of problem-solving skills. In Nielsen's (1999, 2001) aforementioned study, the advanced musicians employed extensive metacognitive skills to evaluate their learning effort, identify problems, set goals, monitor progress and pursue further efforts to resolve problems. Crucial to problem-solving, *metacognitive skills* enable learners to know when and how to apply strategies, monitor their learning and evaluate their efforts (Mayer, 1998). The musicians in Nelsen's (1999, 2001) study problem-solved by selecting and applying strategies appropriate for their tasks. Musicians utilise *task-oriented strategies* to master their tasks, with common strategies including repetition, varying the speed, identifying problem areas, mental rehearsal and section-isolation (Lehmann & Jørgensen, 2012). Instrumental learning research recognises that advanced musicians demonstrate extensive metacognition and a broader range of task-oriented strategies compared to novice musicians (Kim, 2010; Pitts et al., 2000).

Nielsen's (2001) representation of practice is a cyclical three-phase model of interplay between metacognition and task-oriented strategy-use. In this study, musicians firstly approached a problem by evaluating their performance and previous learning efforts, and then set goals based on their perceived problem. They then selected and executed task-oriented strategies appropriate for the task and context, while continuously self-monitoring their learning progress and using self-guided instructions to control their learning. After self-evaluating their performance, they either proceeded to the next problem (if successful), or increased their efforts, adjusted their strategies and reassessed the problem. The three learning phases (before, during and after) are therefore cyclical in the musicians' approach to problem-solving.

Other studies also report advanced musicians' use of problem-solving strategies across these learning phases, although notable differences may exist between individuals (McPherson et al., 2019). Higher-education music students (n=204) reported

setting goals prior to learning, controlling their learning through self-observation and concentration strategies, and reflecting using self-evaluation and coping skills (Hatfield et al., 2017). These processes predicted strategy-use in the next learning cycle. Similarly, Kim (2010) observed higher-education music students to demonstrate self-regulatory strategies, with older students revealing a wider range such as focussing and using mental imagery. As problem-solving demands concentration and effort, children need to develop skills to utilise metacognition and task-oriented strategies during practice. Correspondingly, research also seeks to understand other aspects of independent and self-directed practice, such as motivation and learning environment, as discussed next.

Interaction with learning environment

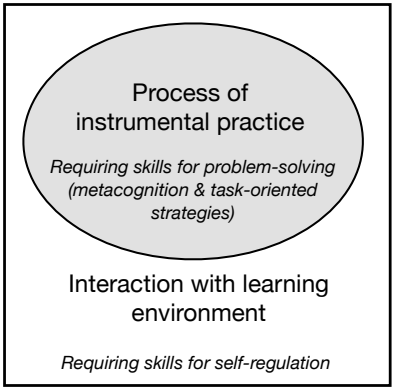
Self-regulated musicians are able to self-motivate, seek help, and manage their own physical environment and practice time (McPherson & Zimmerman, 2011). Several studies have sought to conceptualise the interactions between the musician and their practice environment, as discussed below.

A model to represent personal, behavioural and environmental elements of instrumental practice is proposed by Hallam (1997b). In this model, learner characteristics (e.g. learning styles, motivation, personality) shape how musicians approach their practice. Task requirements, including the nature and performance requirements (e.g. exam), can affect the approach taken. The learning environment, including teacher characteristics, teaching interventions and parental support, can influence learner characteristics such as motivation and self-esteem. Importantly, pedagogical strategies employed by teachers can impact students' practice approach. All these elements shape the practice process (which embodies the aforementioned problem-solving elements of metacognition and task-oriented strategies) and influence learning outcomes such as performance, expertise and future practice efforts.

Other studies have also examined how instrumental practice factors shape musical achievement (Austin & Berg, 2006; Ericsson et al., 1993; McPherson & McCormick, 2006; Sloboda et al., 1996). Studies in this area can result in inconsistent findings due to their diverse range of study methodology, definition of constructs and methods of measurement (Dinsmore et al., 2008). These concerns led Bonneville-Roussy and Bouffard (2015) to develop a model to predict musical achievement. Using data sourced from college music students (n=173), the authors argue that musical achievement is predicted by formal practice, defined as "a goal-directed and focused period of practice that includes both self-regulation and deliberate practice strategies" (p. 686). They contend that motivation and amount of practice can positively impact musical accomplishment, but only if associated with formal practice. However, this model was primarily based on self-reported behaviour which may not always correspond to observed behaviour (Christensen, 2010). Furthermore, it did not account for young children's practice approach and the development of more advanced practice strategies.

It is evident that a model for instrumental practice needs to consider both effective learning and the development of self-regulatory skills. Moreover,

Figure 1: Nature of self-regulated instrumental practice.



it needs to reflect the metacognition and task-oriented strategies required for problem-solving, and to consider children's interactions with their practice environment to develop self-regulation on a broader level (Figure 1). Self-regulated learning theory (McPherson & Zimmerman, 2011) provides a framework to further understand these constructs and the development of learning skills, as considered next.

A framework for problem-solving

Self-regulated learning (SRL) theory (McPherson & Zimmerman, 2011) provides a framework to explore the cognitive, metacognitive and motivational strategies involved in instrumental practice. This theory has been used to examine self-regulatory aspects of classroom learning (Mykkänen et al., 2017; So et al., 2019), and in recent years has provided a framework to explore how individuals approach instrumental practice (Dos Santos & Gerling, 2011; McPherson et al., 2019). The SRL framework specifies three phases to learning: forethought, performance, and self-reflection, representing processes and beliefs that occur before, during and after learning respectively.

These cyclical phases, whereby each phase influences the next, are comparable to how advanced musicians solve problems (Hatfield et al., 2017; Nielsen, 2001). During *forethought*, if musicians approach their practice by analysing their tasks, setting goals and drawing on self-motivation beliefs, they are more likely to self-monitor and control their learning. During *performance*, if musicians self-observe and self-control their progress (e.g. self-instruction, mental imagery), they are more likely to reflect on their learning. During *self-reflection*, musicians who self-evaluate their learning and review their effort and selection of strategies are more inclined to employ self-regulatory strategies in the next learning cycle (McPherson & Zimmerman, 2011).

More broadly, musicians also need to manage their own practice sessions, choose when and where to practice, structure practice sessions and seek help from others (McPherson & Renwick, 2011). SRL theory also provides a relevant framework to explore the development of self-regulatory skills through interactions with the learning environment, as discussed next.

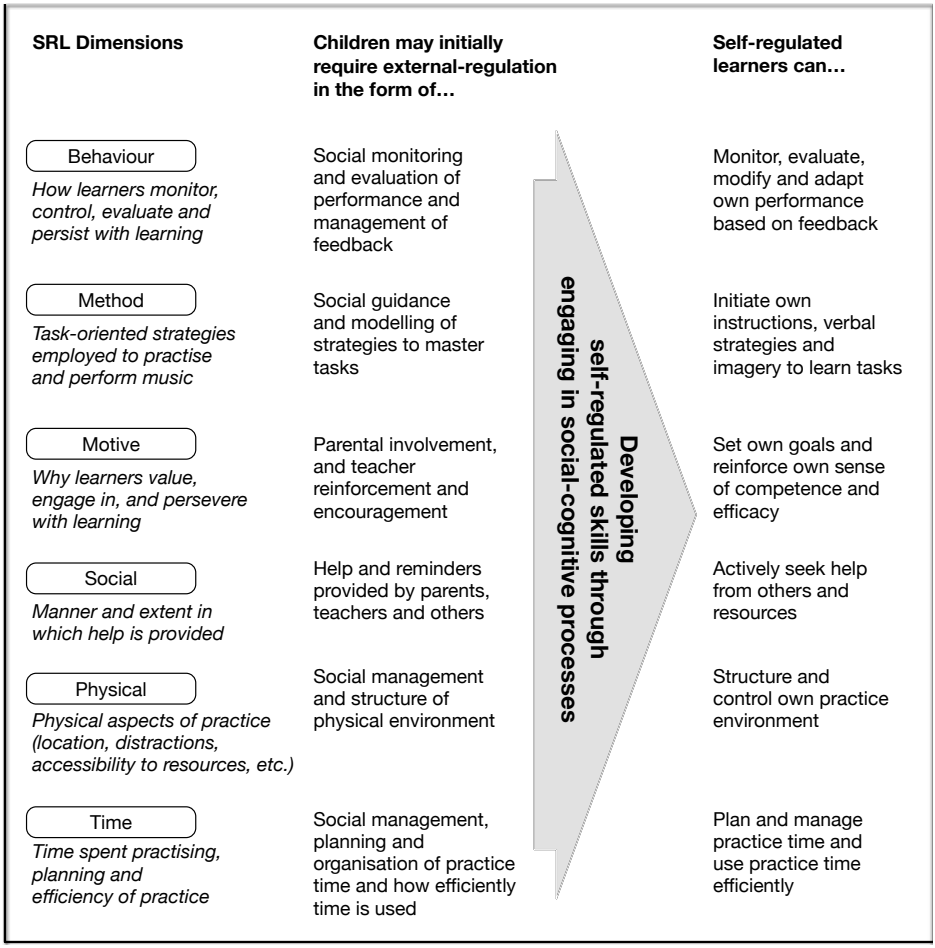
A framework for self-regulatory development

SRL theory is a social-cognitive construct situated within the social constructivist paradigm. Evolving from the work of Vygotsky, it theorises that learning occurs when meaning is constructed during social interaction, through language and within the learner's sociocultural context (Bonk & Cunningham, 1998). Vygotsky contends that children learn to self-regulate by initially having adults directing their attention through words and understanding, prior to developing private speech and internalising speech and thought (Fox & Reconscente, 2008). Correspondingly, social-cognitive processes such as modelling and scaffolding can facilitate self-regulatory development in children (Zimmerman, 2000).

In instrumental learning, this social constructivist approach can be viewed as the transition from external-regulation towards self-regulation through engagement in social-cognitive processes (McPherson et al., 2013). SRL theory offers a dimensional framework to explore this transition. Figure 2 presents an overview of these dimensions and illustrates the context-specific processes of self-regulatory development (as applied to children) (McPherson & Zimmerman, 2011; McPherson et al., 2013). Although progress can be protracted, SRL theory posits that self-regulation can be developed through social-cognitive support (McPherson & Zimmerman, 2011).

As previously discussed, research into the facilitation of self-regulated learning skills requires a theoretical lens that encompasses both the instrumental practice process and children's interaction with their learning environment (Figure 1). Correspondingly, the cyclical model of SRL theory provides an appropriate framework

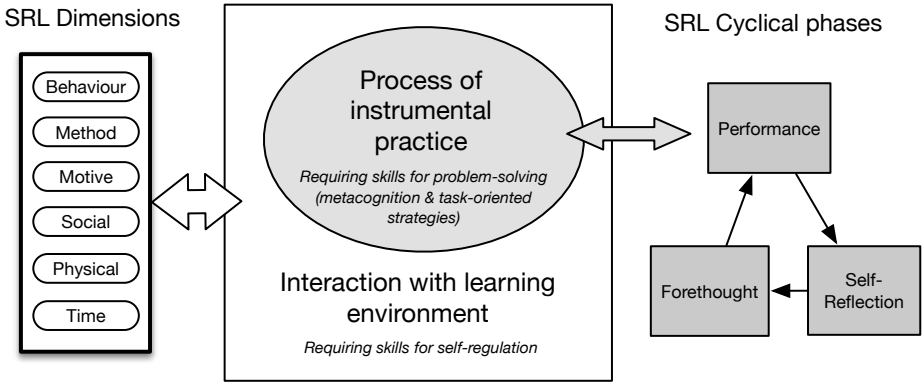
Figure 2: SRL dimensions and social-cognitive processes of self-regulatory development.



for problem-solving and navigating instrumental practice, while its dimensional model offers a basis to explore children's development of self-regulatory skills (Figure 3) (RQ1).

The primary intervention resulting from SRL research is the call for teachers to model and demonstrate a variety of practice strategies to students for a sustained period of time (Hallam et al., 2012; Lehmann & Jørgensen, 2012). During lessons, teachers can encourage self-awareness of strengths and weaknesses, and provide support for learning motivation and development of more independent practice strategies (McPherson et al., 2013, 2015). Nevertheless, these interventions may be ineffective unless students are able to monitor and control their learning when practising by themselves (McPherson & Renwick, 2001). Parents can help children cope with difficulties and develop self-competence beliefs, and their involvement through supervision, goal-setting,

Figure 3: SRL theory for exploring instrumental practice and self-regulatory development.



encouragement and reminders can influence children's development of self-regulation (McPherson & Davidson, 2002). However, not many parents have adequate skills, knowledge or time to provide consistent support and supervision of their child's learning (McPherson & Zimmerman, 2011). Many children require other forms of support and resources between lessons to help them develop the self-regulatory skills required to continue their instrumental learning engagement.

This compelling issue necessitates attention, and SRL theory provides an appropriate foundation for this exploration. To further understand how self-regulated instrumental practice can be facilitated, current knowledge in the intersecting areas between instrumental practice, SRL and DT are important considerations.

Instrumental practice, self-regulated learning and digital technology: A synthesis

Role of self-regulated learning in instrumental practice

Instrumental music research has explored various aspects of self-regulation and their influence on music learning and development (Varela et al., 2016). Further studies and the limitations are considered below.

Studies in instrumental learning generally indicate a positive influence between strategy-use and musical development. In a 3-year study of primary school-aged children (n=157), McPherson (2005) discovered that students were more likely to succeed when they applied musically appropriate mental strategies early in their learning. Similarly, greater self-regulatory behaviour was observed in three higher achieving novice students (aged 9) (Bartolome, 2009). In Hallam et al.'s (2012) research utilising self-reported behaviour of 3,325 musicians (aged 6-19) with varying proficiencies, more effective practice strategies were correlated with higher expertise. Dos Santos and Gerling (2011), in their study which examined 15 college students' practice over 16 weeks, observed that students' self-reports of self-regulation strategies did not always correspond to performance quality. However, Bonneville-Roussy and Bouffard's (2015) aforementioned study concluded that formal practice predicted students' musical achievement.

Research has also revealed relationships between practice time and other music learning factors. In a study of 224 band and orchestra students (aged 11-12), Austin and Berg (2006) observed that students who reported more self-regulatory learning behaviours also practiced more frequently and for longer. Bonneville-Roussy and Bouffard (2015) revealed that practice time positively influences

musical achievement when formal practice strategies are incorporated. Surprisingly, Araújo (2016) discovered that practice time of advanced musicians decreases with age. This suggests that less time is required to achieve goals for musicians with higher self-regulation and efficiency.

Motivation can influence engagement in instrumental learning. Renwick and McPherson (2002) observed a young clarinettist to exhibit more advanced practice strategies and perseverance when learning self-selected repertoire compared to teacher-assigned repertoire. In a self-report study of 446 students undertaking instrumental exams, McPherson and McCormick (2006) found self-efficacy to be the best predictor of performance results but cautioned that other factors need to be considered. Similarly, Nielsen (2004) indicated that music students with higher self-efficacy were more likely to engage in their practice, both cognitively and metacognitively. In Evans and Bonneville-Roussy's (2015) research, college music students (n=392) had higher motivation, preference for challenge and likelihood of practice when they experienced competence, relatedness and autonomy. However, Hallam et al.'s (2012) aforementioned study revealed a weak relationship between motivation and practice amount. Higher motivation was reported at beginner and advanced levels, with further investigation required to determine other factors that kept students practising even when unmotivated.

Self-regulation studies in instrumental learning have largely been descriptive and correlational, with limited research examining self-regulatory interventions on musical development (McPherson et al., 2013). In an experimental study (n=28), music undergraduates who received training on self-regulation principles and practice strategies made significantly greater performance improvements than those instructed only on practice strategies (Miksza, 2013). Conversely, Mieder and Bugos (2017) observed no differences with strategy-use after SRL was taught to 30 high school instrumentalists. Inconsistency in findings may be due to different methodologies, measurement instruments and interpretations of the SRL construct (Dinsmore et al., 2008). These variations and the lack of intervention-based scholarly literature highlight the need for further research on SRL interventions for instrumental learning.

Although instrumental learning research suggests that students with greater SRL skills are more likely to practice effectively, many children may require further support when practising by themselves. A main avenue of SRL research explores how DT can be used as a social-cognitive tool to scaffold self-regulatory development, as discussed next.

Facilitating self-regulated learning with digital technology

Developments in educational technology can offer multiple pathways and representations for authentic and constructivist learning, through meaningful interaction with content, resource-sharing, social dialogue and collaboration (Crawford & Jenkins, 2017; Jenkins & Crawford, 2016; Mudra, 2020). Recent studies also reveal various challenges with technology in educational settings (Selwyn et al., 2017). A majority of studies which examine technology-use in supporting self-regulatory processes were conducted in secondary and higher-education settings (Zheng, 2016). There have been fewer studies for primary school-aged children, as considered below.

One research avenue explores integrated workspaces to foster self-regulatory processes. Literacy students who used SRL-scaffolded e-portfolios demonstrated higher use of self-regulatory processes such as goal-setting and strategy planning (Abrami et al., 2013; Meyer et al., 2010). Meyer et al. suggest that purposeful acts of planning, doing and reflection may have contributed to SRL development, but speculate that greater teacher emphasis of SRL through e-portfolio usage played a major role. In Zhang & Quintana's (2012) study (n=16), students (aged ~12) using SRL-scaffolded environments for online inquiry demonstrated greater efficiency, planning and self-

monitoring compared to peers who used Google. However, further exploration into scaffolding was required as these students generally provided superficial answers to prompts (Zhang, 2013). Comparatively, in research on students' (n=330) use of a multimedia Science resource (with tools to foster each SRL phase), So et al. (2019) observe some facilitation of emotional engagement and cognitive learning but suggest that students' learning skills could have benefitted from more teacher guidance.

Other studies examine the use of SRL-specific components to enhance computer-based learning systems. In a study with students aged 12-13 (n=32), the control group used a basic web-based annotation system to learn English while the experimental group was allocated the system extended with SRL-assistive mechanisms (Chen et al., 2014). Students using SRL extensions considerably improved their reading comprehension and annotation ability compared to the control group, although there were significant gender differences. Similarly, in Lai and Hwang's (2016) study (n=44), the control group learnt Mathematics using a flipped classroom approach, while the experimental group additionally used an SRL monitoring system for goal-setting and reflection. When compared to the control group, the experimental group improved significantly in learning achievement, self-efficacy and planning ability. Both these studies had relatively short durations and small sample sizes with constraints in their methods of measuring SRL.

Although limited, research has shown some benefits when younger children use DT for self-regulatory development. A meta-analysis of SRL studies (involving wide-ranging participant ages) concludes that supporting SRL in DT-based environments can significantly improve academic performance (Zheng, 2016). DT also offers avenues to support instrumental practice, as considered next.

Facilitating instrumental practice with digital technology

Technology can offer new ways to facilitate constructivist music learning and enable artistic expression (Power, 2019; Savage, 2017; Southcott & Crawford, 2011). DT can also foster musicianship skills in aural training, theory, improvisation and composition (Webster, 2015). Technological innovations are providing avenues for wider participation in instrumental learning (King et al. 2019). Various studies of DT-use to directly support instrumental practice are discussed below.

An increasing variety of commercial software programs exists to assist with practice. According to Wan and Gregory (2018), these include practice logs to help plan and record practice, gadgets to monitor tuning and speed, interactive sheet music libraries and accompaniment tools. Birch (2018) explored the use of social-networking to help piano students to reach practice goals. Through sharing their progress with peers, these students fostered social connections, received feedback and encouragement, and engaged in focussed listening. Zhukov (2015) observed that higher-education students are choosing to practise with DT, using software for recording, self-monitoring, repertoire selection and note learning. Feedback tools, designed to improve music performance accuracy, can also assist in some aspects of practice (Wan & Gregory, 2018). Current examples of these tools include Music Prodigy (www.musicprodigy.com), PracticeFirst (www.practicefirst.com) and SmartMusic (www.smartmusic.com).

SmartMusic provides accompaniment and immediate visual feedback of pitch and rhythm accuracy during instrumental practice. Gurley's (2012) research with students aged 11-18 (n=147) found that a majority perceived SmartMusic as beneficial for increasing performance accuracy and practice effectiveness. In an experimental four-week study (n=20) (Flanigan, 2008), college brass students who used SmartMusic exhibited greater development in areas of intonation, expression and overall performance compared to the control group.

However, Long (2011) discovered that SmartMusic evaluated performances based on a restricted set of objective criteria. As its assessments excluded elements such as articulation, style and tone quality, automated assessments (in their current form) are not substitutes for human evaluations (Long, 2011). Considered collectively, feedback tools can support some aspects of practice but do not replace the more comprehensive feedback provided by teachers.

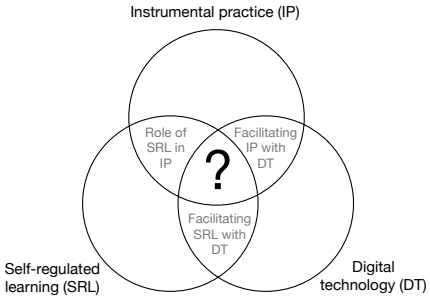
Studies into feedback software have provided some understanding of practice tools, but self-monitoring of pitch and rhythm accuracy represents a small subset of skills required to become a self-regulated musician. Waddell and Williamon (2019) conclude that although musicians utilised DT regularly to improve performance skills during practice, there was a notable gap in their technology-use to support SRL. Research is only beginning to explore how DT can facilitate the range of self-regulatory processes required during instrumental practice, as examined next.

Facilitating self-regulation of instrumental practice with digital technology

Despite emerging SRL research and the growing availability of technology, there are limited studies on how DT can facilitate self-regulation during instrumental practice (Figure 4). Two main avenues are discussed below.

One avenue of research investigates the use of a web-based e-portfolio for the music studio setting. Designed to encourage SRL development, iSCORE explicitly scaffolds the planning, doing, and reflecting stages of instrumental practice (Brook & Upitis, 2014). The tool aims to promote communication and collaboration between students, teachers and peers by facilitating feedback, interaction, and sharing of recordings and resources. Upitis et al. (2014) observed that iSCORE positively influenced the self-motivation and self-reflection of a 15-year-old pianist. However, when trialled with 74 students (aged 8-adult), Brook and

Figure 4: Limited scholarly literature within intersections of instrumental practice, SRL and DT.



Upitis (2014) reported mixed results. Some students found the tool cumbersome to use and required too much data-entry. Their teachers indicated that technological appeal was insufficient in engaging some students in self-regulatory development. In another study with 8 students (aged 6-16), Mazuera (2014) observed some positive changes to self-regulation, but also suggested the influence of teacher emphasis on SRL. Collectively, these studies provide the beginnings of scholarly literature on DT-mediated instrumental practice environments to scaffold SRL.

Cadenza is another web-based application designed to foster SRL (Upitis et al., 2017). Teachers can write lesson plans and track student progress, while students can log practice sessions, write reflections and goals, and communicate with their teacher between lessons. In a six-month study with 30 students, Upitis and Abrami (2017) found Cadenza to positively influence student engagement, exam success and communication between lessons. In another study with 61 students, the three participant teachers reported motivating students through checklists, communication, reward systems and monitoring of student practice effort (Upitis et al., 2017). The authors highlighted how Cadenza transformed learning for 16% of students, but further consideration of the 52% who inconsistently used the tool would be valuable. Although these findings offered some understanding of teaching strategies with

technology, student perception with DT is required to develop a holistic understanding.

The above studies embody the initial stages of literature on technology-use to facilitate SRL during instrumental practice (RQ2). A majority of these studies primarily focussed on teacher perspectives of DT utilisation. It is important to also consider the experiences and practice approach of students, particularly younger children who may require more support to sustain their musical engagement. Instrumental learning studies have largely centred on how teachers can teach practice strategies during lessons (McPherson et al., 2013). There is a present need to shift this inquiry towards the instrumental practice environment and to further explore the role of DT in facilitating children's self-regulatory development.

Conclusion

This paper has identified SRL theory as an appropriate theoretical framework to explore children's self-regulatory development of instrumental practice (RQ1) and concluded that limited scholarly research exists on the role of DT in facilitating learning within this context (RQ2). Using SRL as a theoretical foundation, this paper recommends that further research focuses on student experiences when practising with DT. As Burnard argues, students "have a right to and should be involved (in collaboration with teachers and software developers) in making recommendations about their learning environment and be involved in the implementation of change" (2007, p. 50). Further inquiry needs to explore how technology and pedagogy can work together to promote self-regulatory facilitation, and to examine both limitations and affordances of DT-use (particularly to understand why some students may not use DT consistently). The reliance on self-report instruments in previous SRL research is evidenced in this literature review. As self-reported behaviour can differ from observed behaviour, a research approach that utilises multiple data sources can provide further corroboration of findings (Dinsmore et al., 2008). A DT-mediated study can broaden the perspectives found in current scholarly literature which is primarily descriptive and correlational. Such research can inform software design in creating tools aligned with student learning needs and engagement, while supporting relevant pedagogical strategies to foster positive learning outcomes (Savage, 2012; Webster, 2012, 2015).

Many children will continue to face challenges during instrumental practice, unless practitioners and researchers explore and reconceptualise how this learning environment can be transformed to facilitate self-regulatory development. This study has highlighted the fundamental need to pursue further research in this area, so students can be empowered to become more independent, effective and self-motivated musicians.

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