

TEACHING ADAPTIVELY FOR MUSIC

Smart Opportunities Emerging from the Representation of Score Notation

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Keywords: music education, adaptive instruction, music notation, IEEE 1599

Many developmental approaches have been proposed in literature and are currently in use in order to define music education curricula for young students. In this context, our research aims at describing a computer-based framework for the adaptive teaching of music. A music learning environment can be considered as *smart* when adaptive technologies are employed in order to improve student performance. Research about *effective teaching practice* pointed out that adaptive instruction can provide *school settings* able to foster inclusion and differentiation. Adaptive instruction can be conceptually defined as a set of alternative didactic strategies – either formal or non-formal – within a curricular program which are able to meet the student needs. In our proposal, adaptivity is involved from two different points of view: in fact, adaptivity implies the possibility for the teacher to choose an instruction method fit for the single student, as well as the possibility for students to have a learning environment modelled on

for citations:

Ludovico L.A., Mangione G.R. (2014), *Teaching Adaptively for Music Smart Opportunities Emerging from the Representation of Score Notation*, Journal of e-Learning and Knowledge Society, v.10, n.3, 51-69. ISSN: 1826-6223, e-ISSN:1971-8829

their personal plans, preferences and previous knowledge. This approach can be adopted thanks to a computer-based framework including: i) a multi-layer format to encode music, and ii) an advanced application oriented to music educational content design and fruition. As regards the former aspect, we will briefly introduce an international standard known as IEEE 1599, specifically designed for the comprehensive description of music. The latter aspect will be covered by a software prototype – namely an advanced media player supporting IEEE 1599 documents – freely available via Web.

1 Introduction

The evolution of new technologies and their integration in educational practices have assigned a renewed meaning to the issue of student-tailored teaching. The approaches and techniques used to meet the specific needs of the student are known as *adaptive learning* (Corno & Snow, 1986). The conference of the European Educational Research Association (EERA) held in 2006 focused the concept of adaptive learning within the community of educators. Reference (Bruehwiler *et al.*, 2004) emphasized the importance of describing and understanding the “adaptive teaching skills”, calling educators to field this approach by observing the impact on the learning of pupils. This idea, which goes back to the thought of Wang (Wang, 1980), can be summarized in the ability to continuously monitor, steer and adapt the teaching by evaluating the learning process of pupils. The distinctive feature is the teacher’s ability to respond to specific individualities reinterpreting and revisiting deadlines, objectives and strategies. This capability is commonly referred to as *teaching adaptively* (Corno, 2008): such a locution highlights the interactive nature of the relationship between the student’s and the teacher’s behavior, where the latter subject prepares educational experiences and aims at the achievement of good results from each single student. Adaptive instruction can be conceptually defined as a set of alternative didactic strategies – either formal or non-formal – within a curricular program which are able to meet the student needs (Birch & Reynolds, 1982; Wang, 1980).

References (Westwood, 1996; 2013) state that the *excellent teaching* is the process that fosters learning and guides the development of analysis, synthesis and evaluation skills. Studies such as (Tobin & Fraser, 1991) focus on *exemplary teachers*, namely those teachers who help students reach higher levels of personal success during their formal education. Though they may differ in teaching style and discipline techniques, nevertheless exemplary teachers tend to use common strategies aimed at maximizing the time spent by a student on a given task, thus encouraging active participation in the learning experience, ensuring the understanding of the work and fostering a better performance as well as a good level of success with respect to the educational process (Harris, 1998; Rosenshine & Stevens, 1986; Rosenshine, 1995; Westwood, 2013).

Recent advances in technology and their integration in educational design have enhanced the development of models and approaches to define adaptive learning experiences by accepting the different learning needs and abilities of students (Lee & Park, 2003; Mangione, 2013). Recent works (Vandewaetere *et al.*, *op. cit.*; Mangione, *op. cit.*) introduce a conceptual representation of the adaptive educational process by identifying three main dimensions, interrelated to each other:

- The first dimension refers to the source of adaptive learning – *for whom or what is adaptation performed?*
- The second dimension refers to the target of adaptive learning – *what has to be adapted?*
- The third dimension is a sort of bridge between the previous ones where pathways, namely those strategies and solutions that bring from the initial conditions to the goals to achieve, are identified – *how should data be used, and which methods should be adopted in order to obtain adaptivity?*

The first dimension involves didactic material and its content (Vandewaetere *et al.*, *op. cit.*; Mangione, *op. cit.*; Tseng *et al.*, 2008). The activity of defining the accompanying materials (Vandewaetere *et al.*, *op. cit.*; Mangione, *op. cit.*; Aleven *et al.*, 2006; Bunt *et al.*, 2007), the display mode (Vandewaetere *et al.*, *op. cit.*; Mangione, *op. cit.*; Jeremic *et al.*, 2009; Romero *et al.*, 2009), and other elements that belong to instructional design and learning process – e.g. *cues, prompts*, etc. – is important in facilitating students and their interaction with the environment.

The second dimension includes aspects related to the moment when the adaptive intervention occurs. Adaptation can be either static or dynamic. In the former case, it takes place before the educational task is started, thus it is based on *a priori* measures of the characteristics of the learner. As a result, a suitable teaching strategy is chosen for the learning scenario. This approach is risky because it ignores the effects of context; on the contrary, it has been demonstrated that the results of adaptive education can significantly vary according to the different teaching contexts (Park & Lee, 2003). Since the context is determined not only by the learner's characteristics, but also by intra- and inter-individual differences (e.g., different learning stages), a more dynamic approach to modeling is required. Dynamic adaptation – namely the one occurring at run-time – is performed while the student is interacting with the environment (Schwab & Kobsa, 2002). Research on affective-variables modeling in learning environments (Vandewaetere *et al.*, *op. cit.*; Mangione, *op. cit.*; Woolf *et al.*, 2009;) emphasized the importance of dynamic models, discussing their ability to provide an accurate prediction about the problem-solving ability of students.

Finally, the third dimension focuses on the delivery method of adaptive teaching. Methods can range from instructor-controlled ones (Bunt *et al.*, 2004; Koutsojannis *et al.*, 2008; Shute & Zapata-Rivera, 2007; Triantafillou *et al.*, 2004) to environments where students completely exercise control. In the middle, we find shared control (Vandewaetere *et al.*, 2011; Corbalan *et al.*, 2008), adaptive guidance and adaptive advisement scenarios (Bell & Kozlowski, 2002).

A number of instructional methodologies for music teaching emerged and developed rapidly during the 20th Century. In the following we will list some examples in alphabetical order:

- *Conversational Solfège* by John M. Feierabend, where students move from hearing and singing music to decoding and creating music using spoken syllables and then standard written notation (Feierabend, 2001);
- *Dalcroze Eurhythmics*, developed by Émile Jaques-Dalcroze and based on three fundamental concepts, i.e. the use of *sofège*, improvisation, and eurhythmics (Jaques-Dalcroze, 1918);
- *Gordon Music Learning Theory* by Edwin E. Gordon, a comprehensive method for teaching musicianship through the concept of *audiation*, a term that implies mentally hearing and comprehending music (Gordon, 1979);
- *Kodály Method*, developed by Zoltán Kodály and built on a solid grasp of basic music theory and music notation in various verbal and written forms and include the use of solfège hand signs, musical shorthand notation (stick notation), and rhythm solmization (verbalization);
- *Orff Schulwerk* by Carl Orff and Gunild Keetman, a developmental approach that combines music, movement, drama, and speech into lessons that are similar to child's world of play (Orff, 1973);
- *Suzuki Movement* by Shin'ichi Suzuki, whose central idea is that all people are capable of learning from their environment, thus the essential goal becomes creating the "right environment" for learning music (Suzuki *et al.*, 1973);
- *Yamaha Music Education System*, founded by Genichi Kawakami in association with the Yamaha Music Foundation and conceived to foster musicality that everyone has by instinct, developing the ability, as well as encouraging to share joy, of making music of his own (Miranda, 2000).

The previous list does not claim to be exhaustive, but it provides an idea of the multiplicity of methods available other than the traditional ones. Each method has its own philosophy, characteristics and goals. Nowadays educators are expected to choose the teaching method best suited not only to their abilities

and personal beliefs, but also to their students' profile. In the context of music education, teaching adaptivity is a relatively new professional discipline, and only an educator with the appropriate background and experience is able to adapt the teaching method in order to meet the needs of a specific student. One of the hallmarks of exemplary teaching in music education is the ability to creatively adapt or generate materials based on the individual's specific attitudes, goals and needs. In other words, teachers should develop a delivery approach based on the student's learning and cognitive style.

Mastering many alternative methods has some disadvantages to manage, too. For instance, students with learning difficulties can be easily thrown off track if they are given multiple ways to describe a single music piece. Similarly, the passage from a notation style to another in sight reading can be difficult for beginners.

The idea we propose is providing teachers and students with a computer-based tool to foster the application of teaching adaptivity to a specific aspect of music learning process, namely score notation.

2 Music Notation

The definition of *music notation* implies any system used to visually represent music through the use of written symbols. Modern music notation, often known as Common Western Notation, originated in European classical music and is currently adopted by musicians of different genres and cultures throughout the world. Nonetheless, many other kinds of notation are in use, for a number of historical, cultural and practical reasons.

For the sake of clarity, let us briefly present some examples. From a historical point of view, neumatic system for notating plainchant is commonly in use for Gregorian repertoire, and transcription rules into modern notation were created only at the end of the 19th Century. As regards cultural and geographical issues, please note that wide areas like China, India and Indonesia still adopt their own notation systems, due to their traditions but also to a theoretical music system different from the Western one. Analyzing practical reasons for non-standard notations, we can cite tablature, commonly adopted for fretted stringed instruments such as lute and guitar. Finally, contemporary music – due to its expressive needs and to new instruments and devices available to produce sound – introduced many variants and even new formalisms to encode scores (Stone, 1980). This list of notations other than the Western one contains only few heterogeneous examples and obviously it does not claim to be complete.

If we narrow the field to music teaching, mainly targeting early aged students, a relevant subject is children-oriented music notation.

As regards the acquisition of initial reading skills, an interesting review

of the *Middle-C* approach, the *Intervallic method* and their evolutions can be found in (Emond & Comeau, 2013).

Conjectural and *absolute solmization* systems in music are discussed in (Sultanova & Bariseri, 2012). Many music education methods use *solfège* to teach pitch and sight-reading, most notably the Kodály Method. Figure 1, extracted from (Curwen, 1880), shows an alternative way to depict *solfège* by hand signs, thus providing an intuitive visual aid.

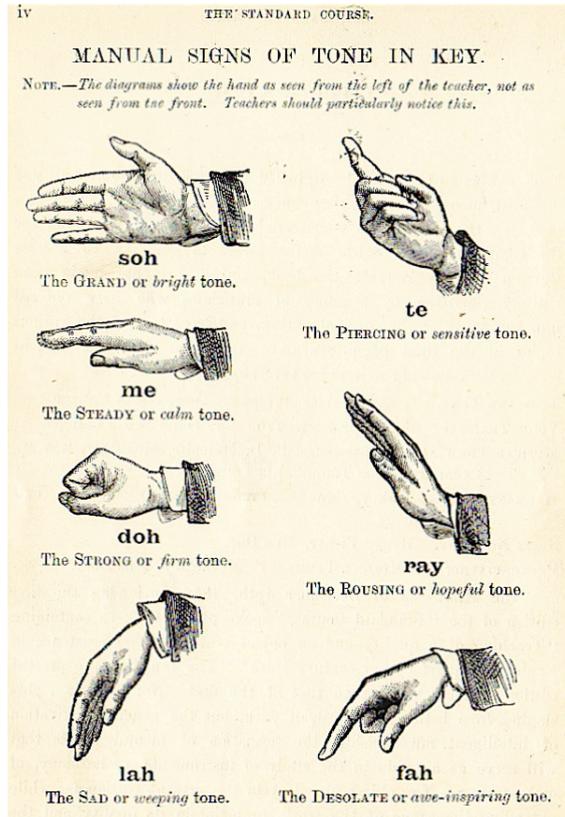


Fig. 1 - An alternative way to depict solfège by hand signs.

A well-known technique to facilitate score reading is *colored music notation*. It is based upon the concept that color can affect the observer in various ways. Scientific literature states that the color-coded notation, even if not meant to replace the present notational system, can be a valid pedagogical aid for beginners (Rogers, 1991). Unfortunately, a standard association among colors and pitches is not commonly accepted. Figure 2 shows a possible translation



Fig. 3 - A music map for rhythmic notation.

Many other alternative score representations have been proposed. For example, (Nijs & Leman, 2014) describes the Music Paint Machine, an interactive system that translates music and movement into a creative visualization. In some pedagogical experiments, even Lego blocks have been used to represent rhythm (through block size) and pitch (through block color).

Adaptive strategies to teach music reading are useful also for students with specific learning disabilities. According to the Individuals with Disabilities Education Act, a student who sustains a *specific learning disability* is a student who has a disorder in one or more of the basic psychological processes involved in understanding or in using language, spoken or written. Disabilities may be manifested in difficulties in cognitive, aural, verbal and physical functioning. With respect to music students, such disabilities range from trouble maintaining focus and attention to difficulties in understanding printed material and discerning musical notation.

In order to devise materials and methods for teaching note reading to developmentally disabled children, fields such as developmental psychology, neuropsychology, special education, and music education are involved. For example, (Smith, 1987) introduces a set of specific directions for teachers to follow when individualizing strategies for teaching musical notation to developmentally disabled children. They include the use of symbols that catch children's attention, content matching to readiness level, the adaptation of teaching method to cognitive style, continuous monitoring of learning rates, motor reinforcement activities, individualized incentives and students preferences, and so on. A solution implemented by some publishers in their editorial products is

presenting music excerpts both in Western notation and through specific color codes in order to facilitate music reading in dyslexic children, as in (Vacchi, 2013).

The process of learning how to read music notation can be slower for students with disabilities and special needs; in this case, it may be supported also by small interventions on content representation. Reference (Zimmermann, 2005) introduces a slightly modified stave notation which seeks to even out symbol size and density, reduce redundant space, place symbols consistently (placing non-pitch and rhythm signs around, rather than on the stave) and to describe in words the location of sporadic or unusual symbols. Finally, let us cite the case of Braille music, namely a code that allows music to be notated using Braille cells so that music can be read by visually impaired musicians (Krolick, 1996).

The multiplicity and heterogeneity of existing notation systems and methods is a key aspect to face when we address the problem of teaching and learning music notation in an adaptive way. Besides, new methods could appear in the future, thus introducing other approaches to represent, describe, or substitute score symbols. Teaching how to read music notation is an activity that requires smart environments able to support content adaptation and *ad hoc* access modes. Each student could require a different time or a different approach, and content adaptation could be targeted as regards not only specific needs, but also personal learning style.

Our goal is supporting as many types of notation as possible within a unique framework, and possibly providing further features to foster teachers in adaptive experience design by using an environment that enables smart instructional actions such as interchangeability, integration and synchronization with other media contents. A possible answer is the IEEE 1599 format, described in brief in the next section.

3 Key Features of the IEEE 1599 Standard

IEEE 1599 is an international standard recognized by the Institute of Electrical and Electronic Engineers (IEEE), sponsored by the Computer Society Standards Activity Board and designed by the Technical Committee on Computer Generated Music. The balloting process successfully ended in 2008.

In IEEE 1599 information is encoded according to eXtensible Markup Language (XML) rules. The choice was originally motivated by the need to have a formal, strongly structured, hierarchical, open and extensible format. Nowadays, this feature allows being fully compliant with the W3C¹ recommendations. A number of multi-platform IEEE 1599 players and viewers have

¹ World Wide Web Consortium, <http://www.w3.org>

been recently implemented in HTML5 and released on the web.

The innovative goal of the format is offering a comprehensive description of music and music-related material within a unique framework, where many different descriptions – either complementary or alternative – coexist. The idea is providing for a given music piece as many descriptions as possible: for instance graphical and audio media objects (e.g., scores and performances), text information (e.g., catalogue metadata, lyrics, etc.), still images (e.g., photos, playbills, etc.), moving images (e.g., video clips, movies, etc.), and so on. This result is obtained in IEEE 1599 through a multi-layered structure, made of the following layers: general, logic, structural, notational, performance, and audio. For further details please refer to (Haus & Longari, 2005).

Moreover, an IEEE 1599 document is more than a mere container for multiple descriptions: such descriptions are mutually linked and synchronized, when possible. For example, all the performances that refer to the same piece – each one with its own base metronome, starting offset, BPM variations – hopefully contain the same list of music events. The occurrence of each music event can be retrieved in any digital object that conceptually contains it, be it a score scan, an audio track, a video clip or a textual description. The way to obtain this in IEEE 1599 is encoding a univocal list of identifiers for music events, known as the *spine*. After marking events through unique ids, they can be described multiple times in the document and synchronization is automatically achieved. Please note that a given music event can have multiple descriptions in different layers (let us consider the graphical aspect of a chord and its audio performance), as well as within single layers (e.g., many different audio performances). Embedding all this information within a unique document allows a rich experience of music contents, as regards both multimedia and multimodality.

For further details about the standard, you can refer to the official IEEE documentation or to a recent publication that explores peculiar aspects of the format in a more explanatory way (Baggi & Haus, 2013).

Computer-supported music education is one of the fields IEEE 1599 can be applied to. In this regard, some aspects have been already covered in (Baratè *et al.*, 2009) and (Baratè & Ludovico, 2012). In this work we will focus on a specific approach, namely the design and implementation of a smart environment to learn music notation by addressing adaptivity in music teaching and learning.

4 An Example of Web Environment

In the framework of the IEEE 1599 initiative, a Web portal has been published in order to make scores encoded in IEEE 1599 publicly available. This environment has not been conceived explicitly for formal music teaching, but it is flexible enough to be declined also as a smart environment in a didactic

context. Needless to say, other *ad hoc* implementations could be realized for specific purposes, such as special education, gifted education, home-bound education, etc. The portal is fully compliant to W3C standards and independent from the hardware and software characteristics of the local system in use. Consequently, any device provided with an HTML5-compatible browser and connected to the Web can access such a portal. The homepage is located at the following URL: <http://emipiu.di.unimi.it>, and a screenshot is shown in Figure 4.

The portal includes general information, official documentation and a community area to exchange opinions, share materials and request clarifications on technological issues. For our purpose, the most interesting section is the *Music Box*, namely a media player that implements in a Web environment all the features of the format previously described.



Fig. 4 - The homepage of the IEEE 1599 dedicated portal.

The portal potentially addresses all users interested in music, at different learning stages and music education, ranging from the passionate listener to the student, from the teacher to the musicologist. Its primary goal is providing a Web interface to experience music in an advanced and interactive way. The interface supports full synchronization among a wide variety of materials, including scores, audio and video. Moreover, for each music piece it is possible to enjoy different versions of any media type. For example, different score

versions as well as different audio performances can be compared. Besides, the fruition of music contents occurs in a synchronized environment, thus implementing an evolved score follower.

For the goals of this work, the key words are *heterogeneity* and *adaptivity*. The former aspect can be obtained through an ad hoc encoding of a given piece, namely a document that includes many score versions and possibly many performances too. In this way, score learning – mainly based on visual fruition – would be reinforced by the listening of the corresponding audio. The latter aspect, i.e. adaptivity, is related to how the player is used by music educators and students. In fact, a rich encoding that includes a number of different notations allows the teacher to choose the most suitable one according to the needs, expectations and progresses of each student. Similarly, a student can select the most appropriate score representation, interact with music contents at different degrees and even compare alternative notations. This kind of exercise can be effective to gain a knowledge of symbolic contents that goes beyond the specific score representation.

5 Case Studies

In this section, a number of clarifying scenarios about adaptive music teaching will be discussed. The common point of departure is the adoption of teaching material encoded in IEEE 1599 format, to be opened through a compliant player such as the one described in the previous section.

Among the information layers available in IEEE 1599, let us focus on teaching music notation. The most relevant aspect in this context is the possibility to adopt different formalisms to encode symbolic information. In some cases, e.g. most contemporary music, a non-standard representation is forced by the impossibility to apply Common Western Notation rules (Cage, 1969). In other cases, the choice is dictated by factors such as:

- Providing alternative notations for students with special needs (Perry, 1995);
- Encoding music-related aspects that cannot be caught by common notation, e.g. dance notation (Hutchinson, 1961);
- Taking into account cultures different from the Western one (May, 1983).

In our proposal, we are focusing on the way this environment can foster teaching adaptivity in the music learning process.

Let us start from a basic application. A teacher explaining music notation can employ the interface described in the previous section as a standard media player equipped with score following features. Even if this example may seem trivial, it is introducing a form of adaptivity. For instance, the interaction with

sensitive areas of the score allows to jump to a given point in the score itself and in the related audio as well. The teacher can use this feature to impart to the student a mental association between score notation and sound. Another possibility offered by such an environment is the creation of repetition structures, namely loops, which can be used by the teacher to make the student practice difficult passages. The mentioned characteristics are supported by the IEEE 1599 format and have been implemented in the portal, so they can be experienced in any available music piece.

Depending on the specific teaching needs, the score follower can be configured and suitable materials can be prepared. For instance, there are different ways to highlight scores, as illustrated in Figure 5:

- A measure-by-measure full-score approach, where complete bars are colored while music is advancing. This “coarse” synchronization is sufficient for edutainment applications;
- A note-by-note full-score approach, where score following occurs at the deepest granularity. This application can be useful for musicology and conducting apprenticeship;
- A note-by-note single-part score follower, suitable for learning a given musical instrument or vocal part;
- A custom approach, where only some music objects are highlighted with a specific purpose to achieve (e.g., teaching rhythmic structures, showing the occurrences of a music theme, etc.).

Now let us consider the case of a class of preschool students: the teacher has to choose the most suitable notation for their needs according to personal experience. An adaptive approach is choosing one of the multiple notation formalisms available in the teaching material, namely in the IEEE 1599 file. This requires the availability of an XML document where many notations have been included.

Since all materials are mutually synchronized, choosing a given kind of graphical representation does not affect the overall music experience offered by the environment. For instance, score following and jumping features are preserved, regardless of the choice of a specific notation.

The figure displays four systems of musical notation for a piece in 3/4 time, marked 'Largo'. Each system includes staves for Flauto (Violino I), Violino II, and CEMBALO. The systems are distinguished by their highlighting of a specific musical subject:

- System 1 (Top):** A red vertical bar highlights the first measure of the Flauto (Violino I) staff.
- System 2:** A red vertical bar highlights the first measure of the Violino II staff.
- System 3:** A red vertical bar highlights the first measure of the CEMBALO staff.
- System 4 (Bottom):** A red horizontal bar highlights the first measure of the Violino II staff, and a red vertical bar highlights the first measure of the CEMBALO staff.

Fig. 5 - Four alternative ways to implement score following: i) the measure-by-measure full-score approach, ii) the note-by-note full-score approach, iii) the note-by-note single-part approach on the 2nd violin part, and iv) a custom approach where only subject occurrences are highlighted.

Moreover, not all students have to practice by reading the same kind of notation. Such a possibility is particularly relevant in mixed classes, where any student potentially presents different educational needs. For instance, a high-contrast, large-symbol version of the score can be produced to cater for the visually impaired, and a color-based representation of pitches can be effective for dyslexics (see Figure 6). Thanks to this smart environment, a teacher can select the most suitable notation for each subject in the classroom.

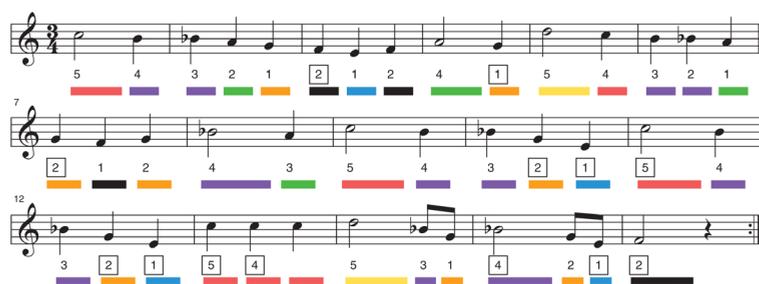


Fig. 6 - An example of mixed score, containing Common Western Notation together with a color coding of pitches for dyslexic students.

The interface described above allows to change in real time any material, both audio/video and graphical, without losing synchronization. The real-time feature can be applied to an adaptive educational environment under different points of view. First, it is useful for comparisons among materials. Obviously, audio performances can be hardly experienced together, so the selection of one of the available audio tracks usually disables the running one. The case of notation is different: in fact, it is possible – and sometimes really effective – to display different graphical materials in parallel, as shown in Figure 6. Some examples of multiple notation for a given score are available in the Music Box area of the mentioned portal (<http://emipiu.di.unimi.it>). For example, the *Introitus* from “In Nativitate Domini, Ad Primam Missam” shows both the neumatic and the corresponding modern notation (see Figure 7), the *Prélude* from “Suite n. 3” by Silvius Leopold Weiss presents an ancient lute score, and *Pas de six: Variation III* from “The Sleeping Beauty” by Pëtr Il’ič Čajkovskij contains also a Labanotation encoding of dance movements.

Another adaptive feature is the one that allows the teacher to make students jump from children-oriented forms of notation – e.g. pictures, colored keys, etc. – to commonly in-use music symbols: this gap can be bridged by the simultaneous use of the two notations within a unique framework, as illustrated in Figure 6.

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