# I-MAESTRO: Interactive Multimedia Environment for Technology Enhanced Music Education and Creative Collaborative Composition and Performance

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# DE4.1.1
# Music Training Paradigms Formalisation

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**Abstract:**
This document reports on research carried out towards concluding a formalisation of a pedagogically- grounded training specification language for music teaching as a component of an innovative framework designed for supporting Pedagogic Flow (PFlow) generation and control at plan-time, execution-time and run/repair-time. This has been inspired with a vision to empower virtual environments for blended Collaborative Learning Communities (CLCs) for which the required reference architecture levels have been described. Thus the resulting designed and implemented i-Maestro pedagogic generation and flow control support framework is applicable to any domain at various levels of granularity i.e. for the generation and chaining of any pedagogic materials (PM) at any levels e.g. music exercise generation or lesson/course planning and generation.

The report examines the various learning modalities and training paradigms. It sets out the state-of-the-art for online learning as well as a comparative and contrastive analysis of the two main contenders in terms of multimedia authorware as candidates for providing the underlying multimedia editing functionalities to be integrated with the i-Maestro Authoring Tool. Accordingly MAX/MSP has been determined as the best choice for integration with the i-Maestro Authoring Tool for which the design of the first prototype based on the above framework has been implemented within this deliverable. In describing the resulting i-Maestro PFlow generation and control support framework, the report explores and specifies the representation of semantic-associative relationships between pedagogic units i.e. the encoding of the evolving Pedagogic Content Knowledge (PCK) as experientially acquired by practicing teachers. Psycho-cognitive aspects of the pedagogic context have been discussed but particular attention has been paid to how the pedagogic delivery context can be best modelled without falling into a reductionist trap which would make for built-in representational rigidities that would prove over-prescriptive and computationally prohibitive for the target execution framework, particularly in seeking to support a dynamic interactive run-time environment.

An innovative deployment of Topic Map Technology (MaestrOnto-SCR), empowered by an overlay representation of Pedagogic Content Knowledge, is proposed to act as a layered ontological networks approach for constructivist elicitation and negotiation of pedagogic knowledge spaces as well as to facilitate the encoding, sharing, updating and exploitation of such knowledge as it evolves. This is also to act as a framework for negotiation and sharing of pedagogic experience within Collaborative Learning Communities, or within oneself by way of introspection, for learning about how best to teach-learn – evolutionary pedagogic refinement. Example pedagogic scenarios are used to motivate the design of a Pedagogic Unit (PU) Schema and a TSL representation for music training which is implemented, as a first prototype, integrated within the MAX/MSP environment to provide support for Pedagogic Flow (PFlow) generation and control as in music Pedagogic Authoring e.g. music exercises authoring and generation. The report illustrates the PU representation by means of schema diagrams and presents the GUI screen shots for the i-Maestro Authoring tool prototype; finally concluding with the PU Schema XML code which is included in the Appendix.

**Keyword List:**
Educational Paradigm, Modelling, Formalism, SCORM, IMS, EML, Training Specification Language, i-Maestro PM Generation and PFlow Control Support Framework, i-Maestro Authoring Tool, Exercise Generation, TSL, plan-time/execution-time/run-time/repair-time flow control.

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# 1. Executive Summary and Report Scope

The work of this sub-WP is focussed on

- The analysis of the state of the art of related and relevant background and standards, e.g., SCORM, IMS, EML, etc;
- Analysis of the modelling for instructions; Pedagogic Flow typology;
- Considering products such as Macromedia Authorware;
- Assessment of the integration capabilities of standard models into MPEG applications for consumer electronics;
- Study, formalising and development of i-Maestro Training Specification Language;
- Definition of a syntax, constructs and semantics of the i-Maestro Training Specification Language;
- Implementing a first prototype of the interpreter for the language processing;
- All the above mentioned aspects in the context of scenarios for music tuition: classroom work, cooperative work, distance learning, assisted work by the teacher;
- In addition, the formalisation will lead to producing models and tools for the assessment;
- The development of basic research and innovations regarding the pedagogical aspects in music education by exploiting the capabilities of IT mainly for the presence and integration of mechanisms for taking into account: human expression, human gesture, interactivity, cooperative work, etc.
- To formalise the specification of innovative music training paradigm with integration, sensors, gesture, and cooperative work with a language and model.

# 2. Introduction

European music educational institutions need to increase their efficiency while reducing costs, in order to be more attractive and effective and to provide a wider access.  The i-Maestro project aims to develop interactive multimedia environment for technology-enhanced music education, with innovative solutions for music training in both theory and performance.  This will be achieved by building on recent innovations arising from developments in computer and information technologies, by exploiting new pedagogical paradigms within a cooperative and interactive self-learning environment, gesture interface, and augmented instruments, with computer-assisted tuition in classrooms to offer support for aural -and practical-training, creativity, analysis, and theory training, ensemble playing, composition, etc..

The main technical objectives of the project include: basic research and development on new solutions and enabling technologies to support traditional pedagogical paradigms for music training.  This also includes novel pedagogical paradigms, such as cooperative-working, self-learning and class-studying, with particular focus on Symbolic Training paradigms and Practice Training paradigms for string instruments exploring interactive, gesture-based, and creative tools. In addition i-Maestro will endeavour to improve accessibility to musical knowledge through devising models and tools to support the creation of flexible and personalise-able e-learning courses.

Music performance is not simply to play the right note at the right time.  The i-Maestro project aims to study and explore many relevant aspects in order to produce methods and tools for music education with innovative pedagogical paradigms, taking into account key factors such as expressivity, interactivity, gesture controllability and cooperative-work among participants.

# 3. Introduction to I-MAESTRO Educational Paradigm

The term "Music Training Paradigm" refers to a set of assumptions, concepts, values and practices that constitute a distinct commonly adopted approach to music teaching that is acknowledged as such by practicing teachers (cf. DE2.1.1e User Requirements, Use Cases, Test Cases and Content Description}. Music training is formalised through the "i-Maestro Training Specification Language (TSL)", to formalise the support for generation and flow control of courses, lessons and exercises (ibid.). A general description of a teaching or training sequence in TSL that can be used as a template for concrete exercises constitutes an "i-Maestro Pedagogic Paradigm" (ibid.)

Music training paradigms in i-Maestro cover Theory Training and Practice Training with a focus on string instrument playing and taking into account different learning modalities, like classroom work, distance learning, study-by-self hereafter referred to as "self-study" and collaborative settings.

Broadly, music learning can be classified into two sub-domains namely formal and informal learning. Formal learning involves understanding and learning music with respect to an already existing pattern and normally this type of learning involves a facilitator or instructor; whereas informal learning happens when the learner learns through intuition and immersion which in turn may become mixed with formal learning later if the learner happens to receive some formal training.

The learning modalities associated with music can further be classified on the basis of learning environments such as:

1) Classroom learning (Formal Learning)
2) Self-study (Informal Learning)
3) Cooperative work
4) Distance learning
5) Teacher-assisted work

Classroom learning is a traditional approach to music learning whereby the instructor teaches the nuances of music to the student in a collaborative learning environment. The teaching is based on the already existing pattern as established for music learning. The most widely used pattern is known as note-based learning. In this model the learner learns to understand the difference between tones by hearing them and the tones are represented using their respective symbolic notation. Although this is the most often followed method being the traditional approach to learning music, it has several drawbacks. Since it adheres to a certain set of strict rules, the process of music learning becomes more mechanical than creative. Resnick (1987), ], stated that formal schooling is 'a setting in which to learn rules' which limit the creativity of the learner. A major setback in using the stave notation is that the visual parameters do not relate to the actual sound as such and beginners find it difficult to relate them to the actual sound [2].

A distinction may be made between immediate correction methods and pedagogy. In the first case, we can speak of "information transmission", i.e. the teacher or the "machine" "informs" the student that, for example, this note is wrong. On the other hand, pedagogy begins, for instance, when the teacher decides to defer the error correction, and wait for the student to hear the error, be worried about it, and feel the need of the correction.

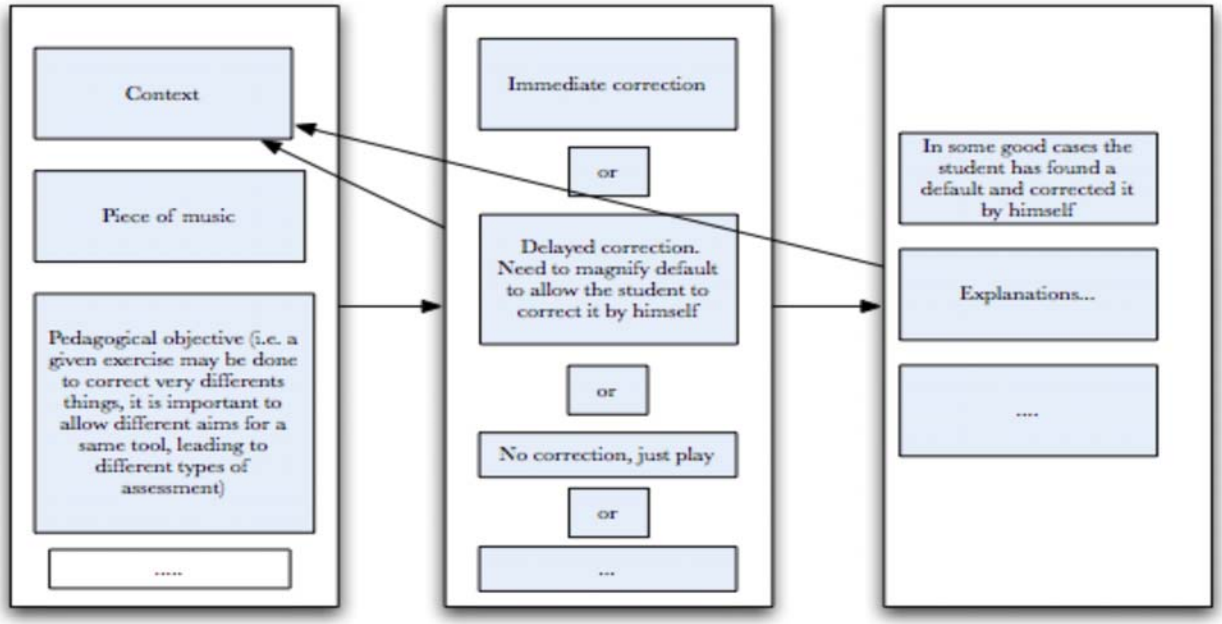


Figure 1: Example of contingent pedagogic flows viewed from a problem-based teaching-learning standpoint

## 3.1 General Learning Modalities

In this section we examine the various modalities of teaching and learning; as illustrated in Figure 2 below:

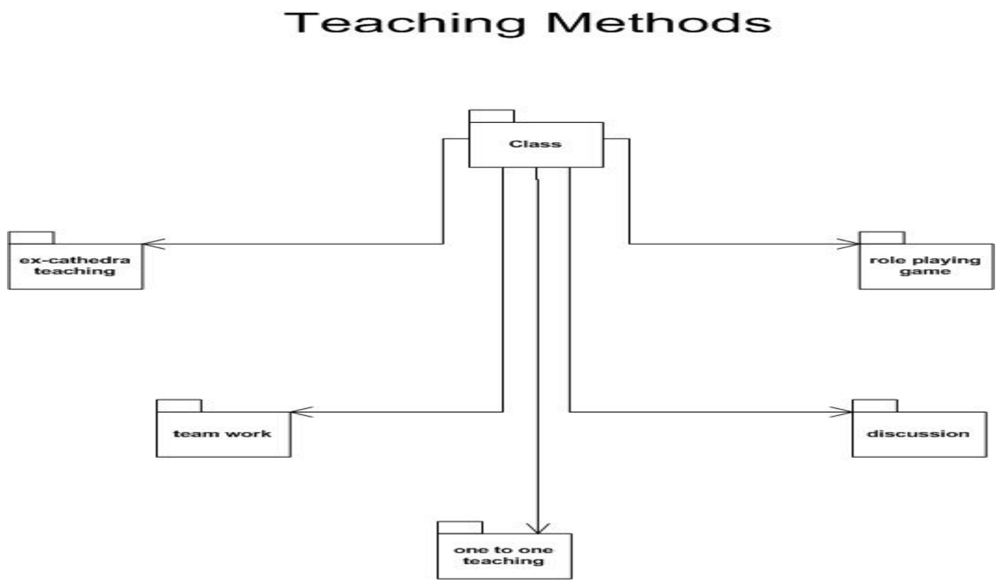


Figure 2: Some existing teaching and learning methods and situations

**Hybrid Forms:**

The teaching situation as characterised by the pedagogic flow control changing as the teaching-learning unfolds during say a session or over sessions/ lessons. On the other hand the adopted teaching method itself is mostly a hybrid form requiring complementary settings thus making for changes in flow control to follow the requirements of the adopted teaching method.

Class teaching, according to Wifried Gruhn and Wilhelm Wittenbruch, [3], shows different forms of interaction. "One to all", the teacher gives all information and the pupils just to receive -"ex- cathedra teaching" in the purest form.

However it is very important to note that all the different scenarios taken into account by i-Maestro can in real life be mutually inclusive and interleaved with each other as a managed mix; e.g. one to one training does not exclude individual-study and so on. The learning path between scenarios is often circular; here some interrelations between scenarios are shown:

Simplest scenario can be illustrated as follows:

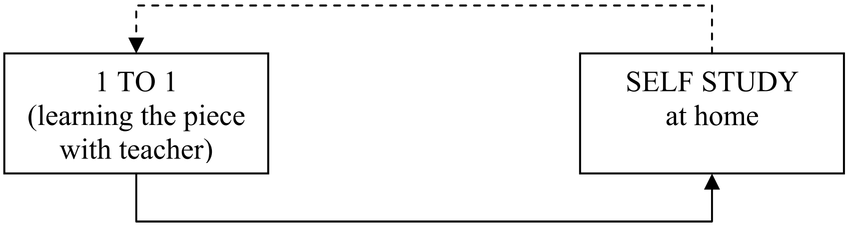


Figure 3: Hybrid teaching forms- a simple example

For CHAMBER MUSIC (each student with his/her own teacher) the learning path is as follows:

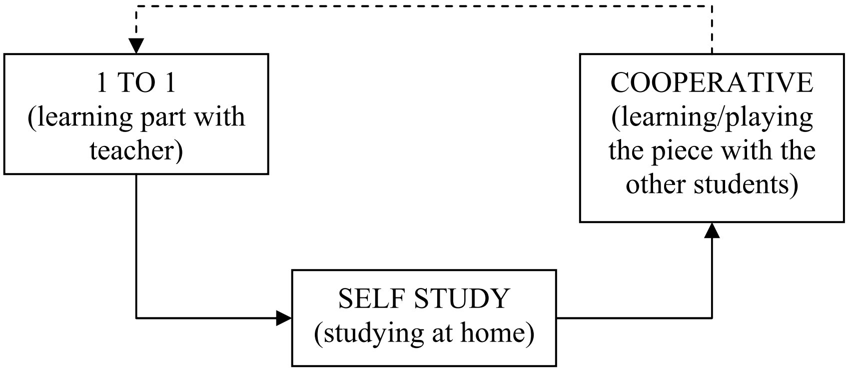


Figure 4: Hybrid teaching: solo and cooperative forms combined

We can consider each box in the above figure as distinct lesson but inter-related with other lessons or consider the three boxes as one lesson given by means of three scenarios. In a quartet, the cycle will involve the stages depicted as follows:

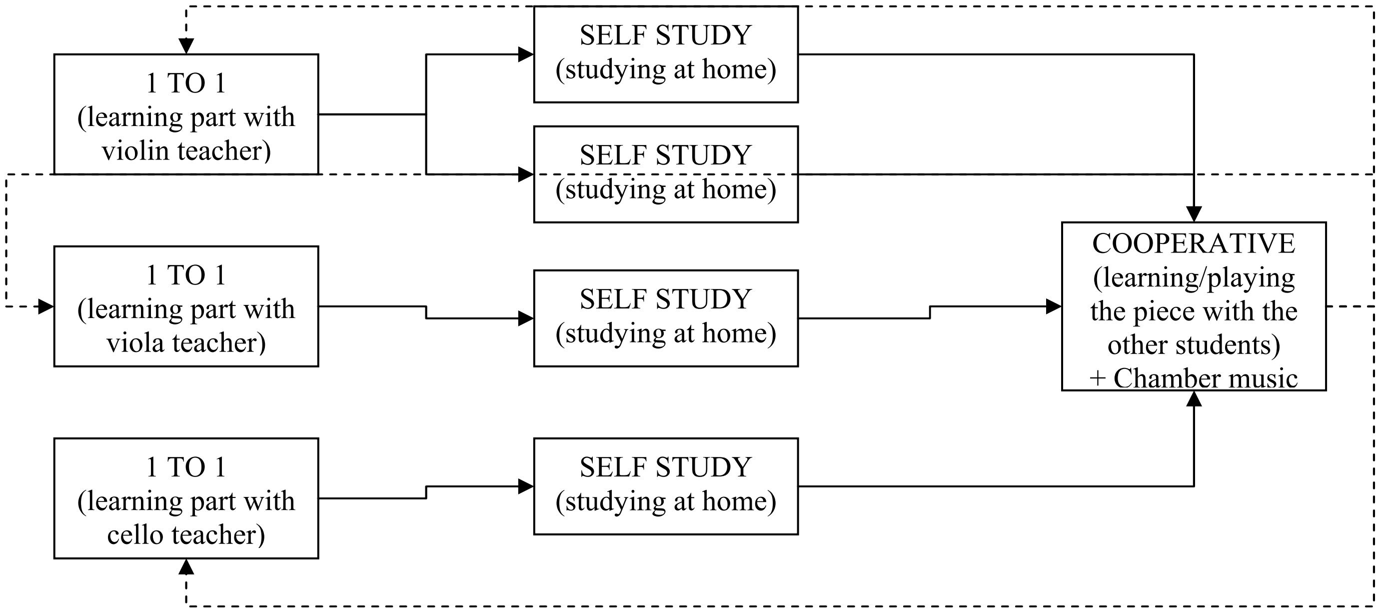


Figure 5: Hybrid Teaching Form- alternative combinations of learning modalities

Note that the cooperation phase as a stage can be with or without a "chamber music" teacher. Each lesson deals with those different scenarios, and at the same time each box is a lesson. Note that in this "quartet case" we have to deal with 4 students and 5 teachers.

Another possible scenario: Two teachers deployed for the same lesson (one for theory, one for practice) as follows:

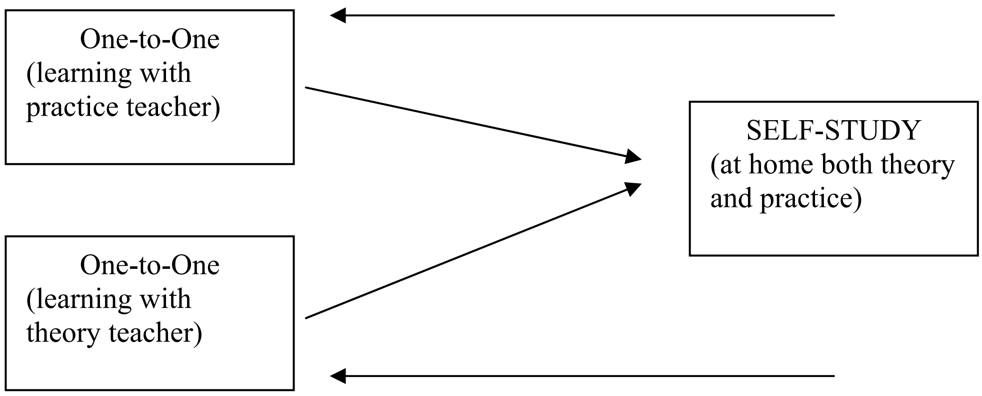


Figure 6: Hybrids form involving a teaching team

### 3.1.1 General Learning Modalities: Classroom Work

The Learning Modalities considered in i-Maestro consist of Classroom Work, Individual-Study and Distance Learning. These terms are defined in the I-Maestro Terminology Document.

Classroom work is defined as consisting of activities involving the interaction between one or more Teachers and one or more Students. Typically, classroom work involves one Teacher with one or more Students. In such a setting, the structure of the classroom can comprise:

- One Student and one Teacher (one to one).
- Several active Students as in Chamber Music class or in Symbolic Music Training (e.g. Harmony or Counterpoint).

- One active Student with several passive (listener) Students.
- One active Student and several Students who participate in discussing the performance of the active Student.

**Example Scenarios:**

- A Teacher teaches in a classroom the fundamental positions for the body, involving issues on Posture/Gesture and the holding of a supported instrument.
- A Teacher is teaching in classroom interpretation (musical concepts) or tone production (beauty of tone) intonation, rhythm...
- A Teacher supervises training in the classroom on specific techniques (e.g. bowing).

Teaching a quartet is typically a classroom activity and could also mean having the following scenario: a quartet of teachers teaching a quartet of students:

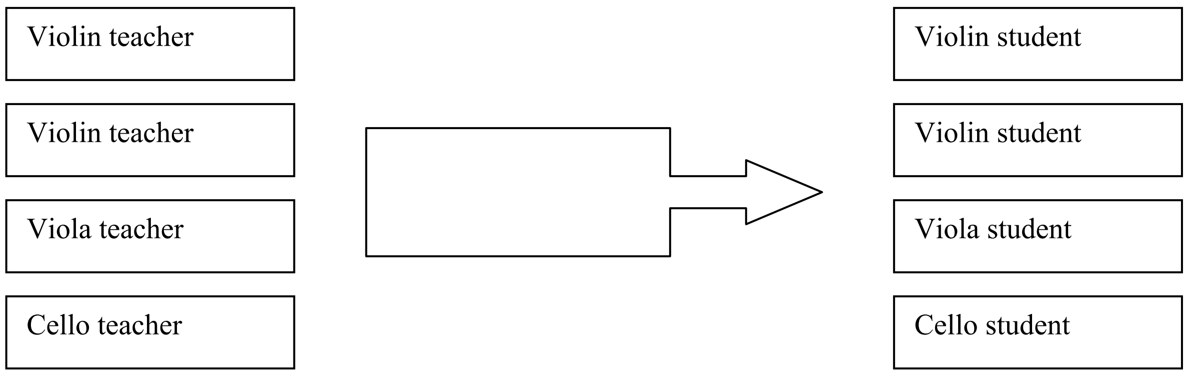


Figure 7: Hybrid Forms: instrument specific teaching team combination

### 3.1.2 General Learning Modalities: Self-Practice

Individual-study is a study setting which is not instructor-led and may involve one or more students studying under their own initiative (autonomous learning). For example, daily study at home. This may apply to practice as well as theory training.

**Scenarios:**

Le us consider a typical scenario for learning to play a string instrument e.g. violin:

- The Student is practising bowing at home.
- The Student is working on good intonation at home.
- The Student is practising different dynamics at home.
- The Student is paying attention to his/her posture and gesture at home.
- The Student is analysing a piece at home (before playing it).
- The Student practices rhythm training at home.
- The Student practices ear training at home.
- The Student writes harmony or counterpoint exercises at home.

Let us remember that such scenarios involve actually decomposing the normal self-study activities into a mix of sub-activities, since during such study activities the student can concentrate on different topics/aspects, alternatively addressing two or more of them, and so on. The same has to be considered for the self-assessment; the assessment concerns, in one single instance, many parameters (pitch, rhythm, dynamics, fingering, bowing, etc…or just one).

Individual-study is a fundamental part of the music learning process. The instrumental lesson is normally once a week (for approximately half to one hour) to provide typically one-to-one assistance to a student to solve technical-interpretative problems, to check the student's progress, etc. For this reason, the pedagogical side of training to support individual-study is very important:

- The ability to work at home efficiently (time and effort)
- The ability to address and elaborate on teacher's hints and suggestions given during the one to one lesson also by means of annotations
- Technique of good habits/practices/ process of self-instruction with daily ritual exercises (like scales, arpeggios, double stops, etc.)
- Supervise their own work (learn the proper way to remain aware of and to overcome faults).

Self-study as described so far in general takes place in addition to formal instruction as in one-to-one teaching or classroom work. This is different from pure auto-didactic learning. The practical experience shows, that there are two groups of auto-didacts.

1. in the age between 13 to 20 years
2. 20 years or older

The first group mostly consists of school boys and girls learning their instruments by playing along with contemporary music, mostly inspired by rock and pop music, i.e. the music they are listening to every day, or producing their own first music pieces using the computer. They may realise that they may not learn enough in school, to write their own songs or really to understand the structures of music. Through searching the Internet for good music theory sites and/or buying some books about music the auto-didacts increase their knowledge.

This mixture of playing along, learning by doing and auto-didactic learning can lead to respectable results, but if a teenager decides to get deeper into the subject or wants to study music then they would need to attend professional music classes.

### 3.1.3 General Learning Modalities: Distance Interaction with the Teacher

Distance Learning is a learning process which involves virtual communication between Teacher and Student across geographically separated locations and mediated by some communication link.

**Scenarios:**

- A Student is supervised remotely by a Teacher.
- The Teacher is monitoring the Student work from a distance.
- The Teacher is playing together with the Student at a distance (showing examples, etc.)
- Sharing spontaneous musical experiences (reactions to concerts, recordings, scores, texts).

In 2003, Monte Belknap, Violin Division Coordinator for the School of Music at Brigham Young University, became the first violin instructor to use peer-to-peer technologies to conduct a lesson.

Advantages of distance learning settings include:

- Experts can teach students in remote areas
- Test- lessons all over the world are possible
- Bringing "un-affordable" experts to small institutions
- Decrease in travelling costs
- Access from any convenient location (mobility and flexibility with irregular work schedules)
- Self-paced learning (intensity, personal knowledge acquisition)

However, distance learning cannot completely replace live one-to-one training and some technical problems due to bandwidth in different countries and delays in communications have to be taken into account even although such problems are being resolved by emergent technologies.

### 3.1.4 General Learning Modalities: One- to- One Teaching

In the string teaching activity the one-to-one scenario covers perhaps the major part of the learning scenarios together with individual study. This happens for some obvious reasons: in the one-to-one modality the teacher can concentrate all his/her effort in order to give the student maximum information and feedbacks about all the topics involved in a music lesson (technique, interpretation, musical thoughts, etc).

The actors in this scenario are: “Teacher” and “Student”. It is important to note that those roles are not fixed but depend on what happens during the lesson. In the I-Maestro environment the student can also be a teacher.

One to one could also be interpreted as “Computer” and “Student” where the computer can substitute for some of the teacher’s functions. In the I-Maestro environment the one-to-one scenario is related to the mapping of the one-to-one real lesson.

### 3.1.5 General Learning Modalities: Scenario Two-to-One:

An unusual scenario takes place when two teachers are involved in the same student’s learning at the same time. In this case, we have a new situation, as the two teachers have different but complementary tasks. The first teacher focuses on practice training while the second teacher focuses on symbolic training; together delivering integrated explanations and thus collaborative instruction. Within this new scenario, which includes a listener audience, it is possible to distinguish two different contexts. The first one happens when the student, as in the usual scenario, receives customised teaching and applies this directly to his/her performance. The second context appears when the teaching turns into a general explanation and is considered as profitable for the listener students, giving more importance to the piece itself.

A detailed analysis of these cases follows:

#### 3.1.5.1 Case one - analysis step by step

**Chair:** Piano
**Actors:** Bloser, Wolfgang (practice training); Eipper, Siegfried (symbolic training); Petzl, Franziska (student playing); listener students
**Scenario:** Practice training master class completed by symbolic explanations
**Composer:** Schumann, Robert
**Work:** Phantasiestüke for piano solo in C minor, op 111
**Movement:** I. Sehr rasch, mit leidenschaftlichem Vortrag
**Topics:** Articulation, Phrasing, Melody

**Work flow:**

- Student plays the fragment.
- First teacher (practice training) stops her and makes an explanation of how the articulation has to be done.
- Second teacher (symbolic training) confirms the opinion of the first one, emphasising the previous explanation.
- Student tries the fragment just with the right hand.

- First teacher gives a new explanation. He establishes a relationship between articulation and melodic form.
- Student plays the same fragment again with both hands.
- First teacher assesses the students' new performance as satisfactory.
- Second teacher explains intervals in the discussed fragment and its relation to the phrasing
- Student plays the passage as performed last time.
- First teacher gives a final assessment, showing his agreement with the student performance.

**Interaction levels:**

- Student with first teacher
- Student with second teacher
- Teachers to each other

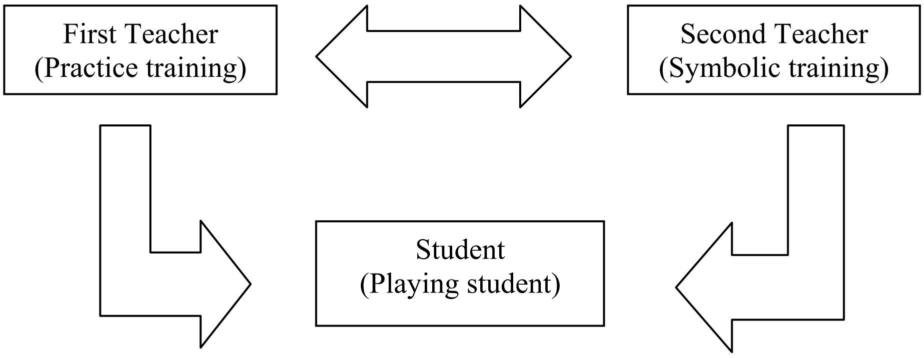


Figure 8: team teaching coordinative pedagogic interactions

### 3.1.5.2 Case two - analysis step by step

**Chair:** Piano
**Actors:** Eipper, Siegfried (symbolic training); Bloser, Wolfgang (practice training); Yu-Ri, Kim; listener students
**Scenario**: Symbolic training explanations illustrated by performance examples in a master class
**Composer:** Debussy, Claude
**Work:** Images pour piano, Book I
**Movement:** III. Movement
**Topics:** Analysis, Fifths, Interval, Phrasing, Melody, Harmony, Dynamics, Left hand

**Work flow:**

- First teacher (symbolic training) makes a deep analysis of intervals, harmonic structure, phrasing and melody.
- Student plays the mentioned fragment just to illustrate with an example.
- First teacher gives a new explanation. He establishes the main materials to be developed in the whole piece (fifths, diatonic motif and diminished design).
- First teacher plays the above mentioned materials.
- Second teacher complements the previous explanation talking about the melody on the left hand and its evolution in the piece.

**Interaction levels:**

- First teacher with the audience
- First teacher with the playing student

- Second teacher with the audience
- Teachers to each other

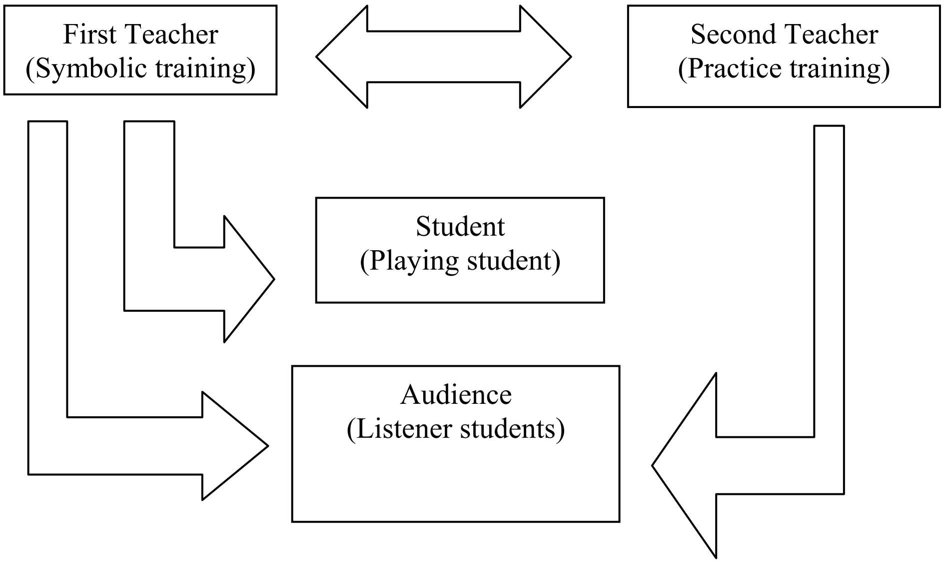


Figure 9: Team teaching coordinative pedagogic interactions involving students playing or listening in turn

#### 3.1.5.3 Building blocks

We can focus on the lesson building blocks for training in string instruments within a traditional one-to-one scenario. The work done by the teacher before the lesson is not taken into account at this stage even although the work explained here reflects the work at home. The content comes from some interviews with string teachers trying to assemble common views but also hints and personal ways of teaching which could be helpful for I-Maestro. The interaction between teacher and the student is obviously unpredictable because of its complexity. I-Maestro should cope with almost every kind of interaction proposed. I-Maestro should provide an enhanced tool to cope with different pedagogical perspectives in the traditional scenario. Any section has of course an assessment function managed by the teacher which is not strictly connected to the "go on" action. The general approach to the mistakes should NOT be just to detect them (once the mistake is detected, the student might not be conscious of the root problem which generated the error). Moreover the threshold of the mistake can be very variable and be too high or too low - in both cases problematic for the student. In our one-to-one scenario we have found at least five sections into which the lesson is commonly divided. The position of each section is somewhat compulsory because, for some of them it is preparatory, i.e. a propaedeutic stage, to the following section. This is just ONE possible model of events but it is widespread in Italy.

- TUNING
- WARMING UP
- PERFORMING
- EXPLANATION OF A NEW TOPIC
- ASSIGNMENT

For each section some notes are included here regarding the features of i-Maestro and some suggestions as to the relevant issues to consider in pedagogic flow generation and control support to be provided by i-Maestro.

In our terms "explanation" of the teacher while the student plays stands for different teaching actions (some are listed as follows:

- *Talking*
- *Playing*
- *Singing*
- *Showing*
- *Annotating the score*

#### 3.1.5.3.1 Tuning

This phase is always the first in a lesson and can occur after every other building block or even in the middle of it: tuning after warming up, tuning after playing, tuning while playing (if the instruments is out of tune the student stops playing and tunes the instrument).

Typically the tuning activity can have two different modalities:

1) In the first modality the teacher (or a tuner) plays a note (generally the A=440Hz) and the student tries to adjust the string to reproduce as near as possible the same note, often with the help of the teacher.

2) In the second modality the student plays the A string in front of a tuner with a microphone that shows in real time if the note produced is too low or too high (with a needle-type metered view).

After the tuning of the A string, the student is also able to tune the other strings playing them together with the A as soon as the interval reproduced is a perfect fifth. Typically the sequence of chords to tune the other strings for the violin is the following: A-E, D-A, G-D. The sequence for the viola and cello is A-D, D-G, G-C.
In contrast with the other string instruments that are tuned in fifths, the double bass is generally tuned in fourths: G2-D2-A1-E1 (high to low). Professional bass players with four-string double basses sometimes have a low "C extension" which extends the lowest string down as far as the low C1, an octave below the lowest note on the cello (more rarely, this string may be tuned to a low B). Since the lowest note of a double bass is the E1 (on standard four-string basses) at 41.20 Hz or a B (when 5 strings are used) at 30.87 hertz, sometimes this is tuned using an electric pickup that is more precise than a simple microphone.

#### 3.1.5.3.2 Warming up

This phase is always after the first tuning. The type of warming up depends on the level of the student and the teacher's needs. For example in the first instance the teacher looks at the student's posture (assessment phase leading into warming up phase), the manner of student's bowing while the student plays whole notes, in slow tempo paying attention to bowing and the balancing of the weight of the arm and so on. This also depends on the repertoire (for warming up to play Bach's cello suites) the student does not need the last part of the fingerboard.

Exercise generator: Long notes (whole notes), Scales, Legati, Harmonics, free sounds
The warming up may or may not match the technical difficulties of the piece/pieces. The warming up phase is also for the instrument not only for the student's fingers and body.

Assessment: posture, sound, weight, bowing.

The warming up can use scores and teacher annotations.

Typically warming up exercises could be related to one or more of the following practice aspects:

- Long notes
- Shifting
- Scales and arpeggio with different rhythmic patterns, bow strokes, accents, etc.
- Double stops (unisons, seconds, thirds, fourths, fifths, sixths, sevenths, octaves, fingered octaves, ninths, tenths
- Vibrato
- Trills
- Harmonics
- Double harmonics
- Intonation
- Left hand fingers independence
- Bow arm exercises
- Exercises for memorising music

In the last century new kinds of gymnastics exercises were very widespread related to different aspects, apparently not directly related to the instrument technique. In fact it is well-known that the teaching of any instrument pre-supposes an acquaintance with at least four branches of science (Mechanics, Acoustics, Physiology and Psychology) and many teaching methods have started also to include some kind of specific physical exercises for muscle relaxation to help players to cope with anxiety, stress, physiological symptoms of stage-fright, etc.[1] [4]. Some of these exercises can be considered as warming up exercises, and can also be performed without any instrument.

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#### 3.1.5.3.3 Performing

The student plays the music. During this phase the interaction with the teacher is very rich. The teacher performs the assessment activity during this phase even although the assessment is formally executed elsewhere in the lesson. The assessment is either related to the whole act of playing or just to one parameter.
The teacher may stop the student at any time if s/he is not playing correctly according to the teacher's viewpoint. Usually the first time the student is allowed to play through the whole piece. After this first performance the teacher who would have already formed some assessment of the performance, gives some feedback, tries to solve problems; proposes exercises, and so on. Generally speaking during this phase the teaching activity after the first performance goes deep into the problems encountered. This means that the student is usually requested to play some passages, single bars, or do some exercises which can help him/her to solve technical problems.

In this case some impromptu exercise generation could be needed. Having an automatic tool for detecting all the possible fingerings from which to choose the correct one considering the different parameters could be useful. The teacher sings or performs any other action in order to explain and communicate technical or musical content.

The teacher may / may not follow the student score with the student's annotations.
The teacher may use other media to help the student to understand.
The teacher may enhance the annotations already present in the lesson score.

[1] In the last years very interesting studies in this field have been performed by the famous Hungarian-born international teacher and lecturer Mrs. Kato Havas who explored the problems inherent in string playing and demonstrates ways of dealing with them based on an understanding of inward-to-outward energy impulses.

#### 3.1.5.3.4 Explaining a new topic

Once the assessment shows progress in remedying the problems encountered, the teacher may begin to explain a new topic. This phase is mainly managed by the teacher. The teacher takes a new score / technical task / exercise and shows the student how s/he has to approach the new topic. In this phase an intensive use of annotations has to be carried for both sides (student can annotate the score while the teacher plays showing him the new topic).

#### 3.1.5.3.5 Assignment

The teacher gives the student some exercises, homework, activities to perform during the teacher's absence, in the period of time between the present lesson and the next one.

There are also different pedagogical schools which have their own building blocks. I-Maestro can take into account two well known schools of violin teaching: Suzuki and Rolland. They represent two opposite approaches to teaching violin, especially for the younger beginners.

The Suzuki method is a way of teaching, and an educational philosophy, most often used in learning to play music. The name is also sometimes used to refer solely to the sheet music books and/or audio recordings which have been published as part of the method. This was invented in the mid-20th century by Dr. Shin'ichi Suzuki. Dr. Suzuki noticed that all children pick up their native language very quickly, and even dialects which adults consider "difficult" to learn are spoken with ease by children of 5 or 6 years of age. He reasoned that if a person has the skill to acquire their mother tongue, then they have the necessary ability to become proficient on a musical instrument. He modelled his method, which he called "Talent Education" (jap. 才能教育 sainō kyōiku), after the process of natural language acquisition. Dr. Suzuki believed that every child, if properly taught, was capable of a high level of musical achievement. He also made it clear that the goal of such musical education was to create generations of children with "noble hearts" (as opposed to creating famous musical prodigies).

The Suzuki violin method which spread its influence globally in the second half of the nineteenth century, is noted here as just an example which is famous and useful for very young students although lately doubts have been raised about its effectiveness. However focusing here on the Suzuki and Roland methods is simply to consider examine a couple of methods to illustrate the more generic flow generation and control support aspects that i-Maestro should consider as the i-Maestro tools are expected to manage music material potentially from all the major methods that are practiced today.

From *Paul Rolland, who founded the University of Illinois String Research Project in the early 1970s, comes the awareness that violin playing must incorporate the most natural physical motions allowing all string players to play with ease and beauty of tone. By applying balanced body positions to violin playing, physical tension is reduced. Rolland made a series of fourteen films entitled* "The Teaching of Action in String Playing", in which he demonstrates innovative ideas for achieve this freedom as an accomplished player.

### 3.1.5.4 Cooperative Learning

In a collaborative or cooperative setting two or more Students are working together (cf. DE2.1.1e). Cooperative learning is possible in theory as well as in practice training.

**Scenarios:**

- Students are practising ear training together.
- Students are working together on rhythm exercises.
- Students are working together on harmony or counterpoint exercises.
- Students are working together on a musical analysis task.
- Students are working together on a composition task.
- Students are practising a piece of chamber music.

## 3.2 General Training Paradigms

### 3.2.1 General Symbolic Training

I-Maestro has to deal with symbolic music paradigms for two reasons: because they are part of the curricula in European countries and because symbolic training in all its components (solfeggio, harmony, counterpoint, history of music, analysis, composition, ear training..) is continuously supporting the training activity in the different learning scenarios. Phrasing, interpretation, and many of the elements of the training lesson are actually based on the symbolic training. The topics of the symbolic training are some of the keys for interpretation, thus they play a crucial part in learning an instrument.

Here some symbolic training activities are briefly described in order to see how they could interact with practice training and what the differences are in modelling lessons. The i-Maestro framework should be able to link or embed practice training topics with symbolic training topics (for example in the study of the various styles of composers). Symbolic or Theory Training comprises activities related to music theory, such as music editing, ear training, rhythm training, harmony training, composition, music history etc. (cf. DE2.1.1e). All such topics can be taught by means of both knowledge units and training units (exercises).

#### 3.2.1.1 Score training

Score training activities are a propaedeutic to music learning. They are supposed to help the students to improve their score-reading capability. An example of this type of exercise is the activities related to solfeggio or similar, where a student is required to recognise a note or an interval or a chord on a music-score shown. For all trainings involving actual use of the score the traditional music notation will be used.

Notation-based learning uses the staves as a tool of representation of the music in space and time. It is a symbolic representation of musical notes. Music notation systems serve as a medium for the storing and transmission of musical output. Furthermore standard music notation is an “international” representation which can break linguistic barriers enabling musicians from all over the world to play together and have a common understanding of the music itself. In this further perspective, music notation abilities in a European educational context must be encouraged and considered in possible curricula at all levels of musical instruction.

Standard music notation has a threefold use as follows:

1) It is a method of representing music
2) It can be used to communicate music between people (mostly musicians), even if they do not speak the same language
3) It is a tool to reflect on the various qualities of music

Although notation lies at the very heart of teaching, learning, composing and playing music, it is a hard and non-intuitive concept for a beginner learner. But still it cannot be eliminated completely because of the reasons stated above.

#### 3.2.1.2 Music editing

This activity is related to music writing. It is an activity that is learnt and practised by music students during their study. It is strictly related to the solfeggio and composition activities. Music editing activities relate to the capability to modify an existing score, to adapt it to a given context or to follow specific requirements.

#### 3.2.1.3 Ear training

Ear training is one of the most important activities performed in order to teach string instruments, thus it will be one of the major tasks for I-Maestro taking into account what already exists and making some innovative and significant contributions to support this type of activity. Ear Training as an activity itself it has two aspects:

- Ear training outside the training lesson can be dealt with as a separate matter. In i-Maestro it requires the automatic generation of exercises following the rules decided by the teacher.

- Ear training as a tool for continuous teacher/self assessment of the pitch and sound quality during the training lesson.

Ear training activities are very important for the musician's development and particularly for developing their sensitivity and accurate hearing. For example, a student is required to recognise some melodic and/or harmonic intervals or all the activities related to the recognition of accurate pitch information. Ear training is also related to acoustic phenomena regarding music in a broader sense (timbre of the instruments, waveforms and other components of sounds and so on) and this is particularly important in increasing students' consciousness of the world of sound. In these cases, ear training is considered as practice-training.

#### 3.2.1.4 Rhythm training

This is considered a part of the ear training, particularly focusing on rhythm. It consists of all the activities that help the student to improve his/her rhythmical understanding and precision during a performance. For example, in a typically rhythmic training exercise, the student is requested to reproduce or guess a rhythmical structure or, better work rhythmically with a difficult passage of the practice training.

#### 3.2.1.5 Harmony training

Harmony includes the examination of the salient characteristics of chords, how chords are connected, the formal requirements for harmonic contrasts and of how gradations of such contrasts can be accomplished and, tonal relationships. All these aspects can be examined using a specific instrument. The harmony training has to be connected with curricula since in many countries harmony is a complete course, not just a matter of exercises to solve problems. This matter has to be strictly connected with Counterpoint.

#### 3.2.1.6 Counterpoint training

Counterpoint is the study of the rules for writing music with two or more melodic lines that occur simultaneously in separate voices. Training of counterpoint is an important part of the teaching to introduce the logical structures of Western Music. It can be learned at different levels of complexity (e.g. canons, fugue and beyond). The counterpoint training has to be connected with curricula since in many countries counterpoint is a complete course, not just a matter of exercises in order to solve technical problems. This matter has to be strictly connected with harmony.

#### 3.2.1.7 Composition training

Composition training activities involve creating/writing symbolic music notation using musical rules, creativities and expressions such as harmony, counterpoint and orchestration (in this case just for strings). Many other activities are involved in composition training. The composition training has to be connected with curricula since in many countries composition is a complete course. This matter has to be strictly connected with Harmony and Counterpoint.

#### 3.2.1.8 Lesson model

In this section we attempt to highlight the building blocks of the symbolic music lesson as it is performed within a traditional pedagogical scenario. The work done by the teacher before the lesson is not taken into account at this stage even although the work explained here reflects and builds on the work done at home.

The observations here are based on excerpts from some interviews conducted with teachers in attempting to assemble common views but also hints and personal ways of teaching which could be helpful for i-Maestro. The interaction between the teacher and the student is obviously unpredictable because of its complexity. I-Maestro should cope with almost every kind of interaction proposed. It should provide an enhanced tool to cope with different pedagogical perspectives in the traditional scenario.

Any section has of course an assessment function managed by the teacher which is not strictly connected to the “go forward” action. As can be seen in the training paradigms, the general approach to the problem based teaching is not just to detect mistake but to examine the genesis of it. This is because once a mistake is detected the student might not be conscious of the root of the problem which generated the error. Moreover the threshold of recording a mistake can be variable and lie at extremes; i.e. be too high or too low, both of which can be disadvantageous for the student. For example writing hidden fifths can be a mistake or not depending on the context (as in double choir counterpoint, Bach choral or dodecaphonic counterpoint).

In this context exercises have a distinct role which is completely different from to that of the exercises as generated by the exercise generator in the training scenario. The exercises here are the CORE of the learning process.

Symbolic training is ALWAYS connected with training for different level of integration depending on the student's level. The following table illustrates an example:

| Level | Symbolic Component in a Training Lesson |
|---|---|
| Beginner | Solfege |
| | Music reading |
| Intermediate | Harmony |
| | Counterpoint (beginner level) |
| | Music history |
| Advanced & master | Harmony (as a tool for interpretation) |
| | Counterpoint (as a tool for interpretation) |
| | Analysis of musical forms (as a tool for interpretation) |
| | Music history (as a tool for interpretation) |

It should be noted that, for beginners, very often when the teacher stops the student having observed a mistake, the student is asked to perform a symbolic exercise using the music he has to play (like solfege it, do rhythm reading, and so on…). This means that same content for both symbolic training and playing lesson have to be available as mutually supportive elements.

In our one-to-one scenario we have found at least four sections into which the lesson is commonly divided. The position of each section is somewhat compulsory because, some of them are propaedeutic with respect to their following section. This is just ONE possible model of the pedagogic flow but it is one that is widely practiced –at least in Italy.

- CHECKING, VERIFICATION and VALIDATION of the content/exercises of the previous lesson. (this section of the course does not exist in the 1st lesson)
  Inside such sections there is the explanation of errors and topics for questions and answers (the teacher confirms or disconfirms certain issues proactively or in response to student's question e.g. says: "Yes this is correct but this other one has a more musical meaning… is better… etc…"
  Annotations are a crucial tool for this section, thus the annotation support tool is a must here with all its capabilities (all drawings, colours, and so on)
- EXPLANATION OF A NEW TOPIC
  This phase is mainly managed by the teacher. The teacher takes a new score / technical task / exercise whatsoever and shows the student how s/he has to approach the new topic. In this phase an intensive use of annotations has to be done for both sides (the student can annotate the score while the teacher plays showing him the new topic)
- ASSIGNMENT

For each section there follows some notes regarding the features of i-Maestro and some suggestions.
In our terms "explaining" by the teacher stands for different teaching actions (some are listed below)

- *Talking*
- *Playing*
- *Singing*

- *Showing*
- *Annotating the score*

## 3.2.2 General Practical Training

This section seeks to establish an overview of different aspects that have to be taken into account when introducing technology support in the context of Practice Training. This context relates to activities involved in instrumental playing and performance, such as play training, improvisation training etc. (cf. DE2.1.1e)

- *Singing/oral training*: singing/oral training exercises are designed to improve the students' musical ear and their capability to play in tune. In modern music education, this aspect is very important. An example of this type of exercise is pitch and intervals recognition.
- *Play/practice training*: for this type of activity, students learn to improve their instrumental control. This activity is structured into many sub-activities, including:
  - *tune/ear/aural training*: to learn to play in tune by improving the musical listening skills and understanding;
  - *instrument technique training*: to improve instrument playing techniques, virtuosity, and mastery of the instrument;
  - *rhythm training* with instrument: to improve the playing skill to perform complex rhythmical structure with the instrument; and
  - all other activities related to the improvement of instrumental control.
- *Improvisation training:* to follow established rules to teach the best way to produce coherent improvisations in real-time. This is particularly important for musicians who want to develop their improvisation and creativity skills, and it has many useful applications. For example, music teachers who are looking for new inspiration for their work with students, and teachers of all subjects and levels using improvisation skills as the inspiration for group work, music, art and movement therapists, occupational therapists as an additional resource, music lovers as an evolution of their spontaneous access to music, and so on. One of the most important aspects for improvisation is to assist inhibited and blocked/repressed people to improve their spontaneous expressions through music.

The Practice Training context involves a complex set of phenomena. Depending on the level of the student, the repertoire and the instrument, the pedagogic flow may need to change completely. For instance, a beginner may build in his mind representations of music from the first gestures that he has learnt, relying on psychomotor memory. In contrast, an advanced student can continue to refine and enrich his mental representation directly from the specificities of the learnt piece.

A distinction may be made between instruments that may produce a note with a fixed gesture (a flute for instance has only one position for producing a single note) and instruments that can use very different fingerings for the same note, depending on both technical and musical constraints.

In the first case, the memory of a single passage is very close to the physical and muscular memory, in the second case, the root of the operative memory needs to be at a higher level of abstraction and generalisation. This higher level may be connected to theoretical knowledge, such as tonal changes or cadences.

### 3.2.2.1 Practice training content

As for pedagogic material (PM) generation phase, practice training can require support with the following:

- Work on repertoire pieces
- Pedagogical tricks during practice training
- Work on interpretation and expression
- Technical exercises (edited books and customised exercises by the teacher)
- Dependence and links between theory and practice

#### 3.2.2.1.1 Work on repertoire pieces

This work may have variable flow characteristics depending on the student's level. For the same *piece*, the required skills may be adapted to support a given pedagogical aim. This is less true for the repertoire called "studies", or *etudes*, which concentrate on a very specialised difficulty. The first class pieces allow more "freedom" from the teacher's point of view, while the second leads to a more specifically indicated process.

| Type of work | Exercise | Etude | Piece |
|---|---|---|---|
| Characteristics of work | Mechanical, very easy memorisation, basic difficulty (regularity…) | Hybrid form involving exercises and the piece, mono-dimensional difficulty (e.g. etude on arpeggios), medium memorisation difficulty | • Understanding of musical form needed (e.g. what is a sonata ?),<br>• strategy of the work (study all occurrences of a theme…),<br>• often longer than an exercise or an Etude,<br>• possibly work in the context of chamber music with other students |

Nevertheless we are aware that very often Etudes and Pieces amount to the same thing are from the musical viewpoint and aesthetical. An etude can be considered a form; in this sense it has to be considered under the piece category.

While working a given musical piece, the teacher may decide to stop the student and make him play a related exercise. The pedagogic flow of a lesson may thus allow a multi-directional graph between each type of work. More often, at the advanced level scenario, the teacher waits for the student to finish playing before giving any feedback and correction.

#### 3.2.2.1.2 Pedagogical tricks during practice training

The following techniques used by teachers in the context of Practice Training are examples showing the complexity of efficient pedagogical work.

*Audio mirror*
The student and the teacher may very rapidly alternate playing a very short segment of music. The speed is critical. When done very fast, this situation allows the student to progressively correct a fault (generally intonation), by trying to imitate very precisely and intuitively the teacher's gesture.

If the exercise is played too slowly, this gives the student time to think alternative pathways to convergence of his performance with what he has just observed done by the teacher and this tend to detract from his chances of replicating the observed performance accurately and may cause him to take longer to succeed.

*Amplification*
Many students' intonation errors occur due to a lack of attention to some details. The student may have difficulty in focusing on a precise detail of a phrase. In such situations, the teacher may play the phrase like

the student, amplifying the fault to make it more obvious. This kind of magnification may occur in other pedagogical situations, when the teacher wants to explain something more clearly, not necessarily a fault.

*Gesture following*
While the student plays a given phrase, the teacher may make gestures as though he were conducting the student. The student may follow the gesture to correct *rubato*, dynamics, intonation etc.

#### 3.2.2.1.3 Work on interpretation and expression

At a high level, interpretation is studied during master classes or advanced courses. The content is less technical and often linked to theory. On the other hand, for beginners, interpretation and expression starts from their own personal experience and is "shaped" using a musical technique or piece. For advanced levels, interpretation and expression comes more frequently from the piece itself, mainly because they access a more complex, profound and "deep" repertoire.

#### 3.2.2.1.4 Technical exercises

Exercises may be divided into two main classes. The first one refers to general exercises such as scales, arpeggios, trills, that may be practiced at any level. In this case, the assessment differs regarding the level and the pedagogical goal the teacher has in mind. The "warm up" exercises fall into this category. The second type of exercise refers to a specific difficulty found during the study of a given piece. Both categories may be taken from existing books or written by the teacher on the student's notebook. A teacher may also decide to use an exercise that does not necessarily match the student's skill or level, because he may be following a different pedagogical goal.

Exercise material can have various sources, for example:

- Printed books and customised exercises by the teacher
- Notebook for handwritten exercises

Different pedagogical goals can be based on the same exercise material.

#### 3.2.2.1.5 Links between theory and practice

*Access to examples from other musical works.*
The teacher may ask the student to listen to recordings of the studied composers for instruments other than the one that is actually being practiced. He may locate a specific theme, for instance, as used in several works.

*Emphasise a theoretical issue related to a current piece or exercise*
This can be achieved by playing only a voice, or by changing the dynamics to make a theoretical point more obvious. The teacher may extract the harmonic progression of a phrase and play it. He may isolate a single voice on a polyphonic work, play it and enhance some compositional issues. These issues are frequently described using music theory terms and knowledge.

*Communication between theory teacher and practice teacher to share ideas on pedagogical objectives*
It is common for two teachers to communicate using the student's notebook. For instance, the instrument teacher may ask the *solfeggio* teacher to emphasise the teaching of a student on a specific, say, rhythmic problem (triplets, and tuplets for instance).

#### 3.2.2.2 Generic support re techniques, tools and work spaces

The following aspects have to be taken into account in the design of a framework for pedagogic flow generation and control support:

- Techniques of feedback and assessment
- Transmission of work assignment, recommendation, and assessment
- Monitoring of progress and difficulties over time
- The instrument and other involved objects and devices
- The work space (class room, exercising studio, etc.)

##### 3.2.2.2.1 Techniques of feedback and assessment

Efficient learning depends on the student's perception of his own difficulties, his progress and the rationale for the deployed learning strategies. In Practice Training teachers have to develop efficient strategies to communicate the quality of the student's performance. The employed strategies have not just to be adapted to the student's specific difficulties and skills but also to his/her (musical) personality and individual strengths.

If a problem is corrected without the student's full understanding and accurate perception of the root of the problem, then the problem may reappear later.

The following aspects are listed as examples of widely adopted advanced techniques re aspects of feedback and assessment.

*"Mirror" techniques*
Pedagogical mirror techniques as described earlier refer to situations where the teacher and the student play the same fragment alternately. The student imitates the teacher, or the teacher tries to improve a fault in the quality of the student. The mirror may also be used to correct a posture.

*Exchanging the roles of teacher and student*
In this scenario, the roles of teacher and student are exchanged. The teacher might imitate some of the Student's problems, while the student acts in place of the teacher.
This situation can be viewed as another kind of mirror. The student perceives the same piece or exercise from a different perspective (without playing himself). By imitating the student, the teacher makes the student see himself through a magnifying glass. When difficulties are corrected in this way, an emotional memory is tagged to the acquired skill, making it stronger.

*Delayed feedback and error correction*
The teacher may correct a certain difficulty of a student immediately when it occurs. He may also decide to delay this correction for several reasons as follows:
- The pedagogical goal is elsewhere. For instance, if the students works on a rhythmic difficulty, pitch correctness may be put temporarily aside
- The student may not have yet the skill to correct the error
- The student does not hear the fault by himself, and does not feel that there is an error to be corrected. The teacher waits for the student to be more advanced to hear and correct the error.

*Magnification of difficulties*
In certain situations it can be adequate to overcorrect a posture or a phrasing by showing and asking the student to adopt an incorrect position or phrasing pulling everything in the opposite direction. Such errors can rarely be corrected by immediately taking the right posture. The learning curve can be illustrated as in the following figure:

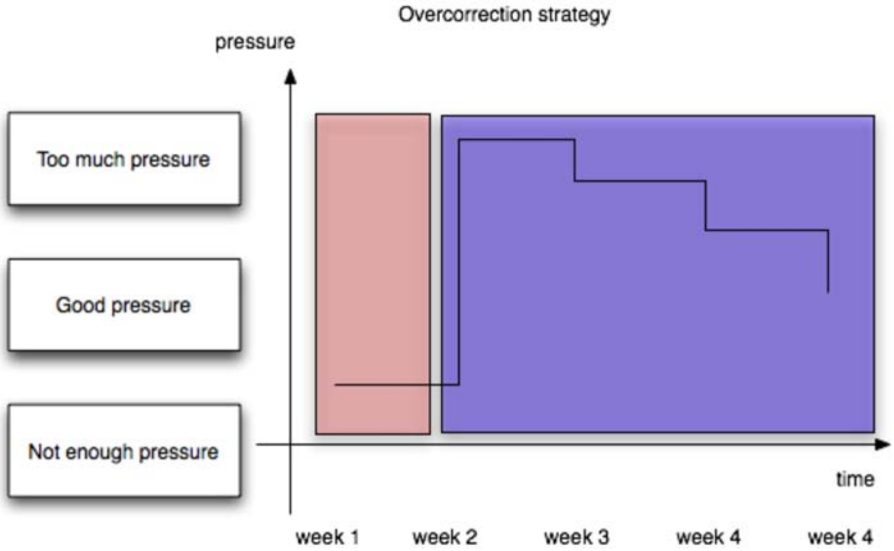


Figure 10: Changing Patterns of Intervention as (over)correction strategy in problem-based teaching

The magnification of a certain difficulty of a student is a common technique allowing the teacher to point out a fault or a quality. Combined with the mirror technique, it is a generally useful pedagogical technique. Experience has shown that a skill acquired by overcoming a difficulty using such techniques is stronger than if acquired otherwise. When a skill is mastered in this way, it is associated with the memory of the pedagogic flow that led to it. The memory represents an important aspect of the student's progress.

Furthermore the magnification of a student's practice difficulty by the teacher, as in the mirror technique, may allow the student to unpick the root of the problem by himself. In other words the student is thus supported in auto-assessing his work.

*Exchange of ideas amongst teachers*
Teachers exchange both private and public information regarding a student. Private information refers to technical aspects that would be difficult to explain to the student. Public information refers to technical aspects which they wish to emphasise, for instance, a rhythmic difficulty that the violin teacher detects in the student may be explained during the theory course. Teachers may also wish to exchange global information related to the school, musical ideas, and pedagogical ideas.

#### 3.2.2.2.2 Transmission of work assignment, recommendation, and assessment

*Transmission from teacher to student*
Harmony and counterpoint students communicate frequently with their teachers through the notebook. Instrument teachers may also transmit work, recommendations and assessment using the score by annotating it. A score may contain annotations directly related to the assessment of work. A score which has been worked and played may be heavily annotated by both the teacher and the student, allowing one to see where the student had difficulties, what type of interpretation was recommended by the teacher. An annotated score may thus represent the pedagogical profile of the student.

*Exchanges amongst teachers*
Teachers may exchange data on the assessment of groups of students or individual students. They may also play or work together, exchange pedagogical ideas.

*Exchanges amongst students*
Students often compare their courses and performances. They may be at different levels and have a teacher/student relationship. If they are at the same level, they often tend to compare the recommendations that they have received from their teacher for the same piece. It is a common for such situated

recommendations to seem contradictory. The teacher may explain that for each student, the same piece can be played differently, with several interpretations and differing pedagogical goals.

#### 3.2.2.2.3 Monitoring progress and difficulties over time

Different techniques may be employed in order to monitor progress and difficulties of a student over time.

*Monitoring of progress by recordings.*
By listening to old recordings of exercises or pieces played several months or years ago, a student can be conscious of their progress. The teacher may use this information to anticipate the kind of pedagogical goals and learning curve s/he has to plan for that student (i.e. the teacher exercise Meta-scaffolding-PCK, see sections 6 -8 later).

*Replay pieces or exercises that have been studied several years before to feel the difference in musical fluency*
When the student plays a piece or an exercise for the first time, the feel of mastering a difficulty is generally polluting the musical expression. When the same piece is played, say, a year after, the ease of playing allows the student to concentrate on musical nuances that could not be studied before.

*Ask the student to be an assistant-teacher during the course of teaching another student*
This is similar to the above situation, but more complex to monitor by the teacher who has to take into account external aspects (e.g. the two students may or not be friends, etc…).

#### 3.2.2.2.4 The instrument and other involved objects and devices

The student has frequently an affective relationship with his personal instrument. He takes care of it; and may show his attachment to it in various ways including writing or drawing on the instrument casing. Each instrument has its own sound, and an insightful and inspiring pedagogical effect can arise when the teacher takes the student's instrument to play. The student recognises the specific sound of his instrument played with the skill of the teacher.

Apart from the musical instrument itself and the musical material (scores), the following objects and devices might be involved in Practice Training:

- Music stand
- Metronome
- Exercise book
- Tuning fork (not for string instruments)
- Tuner (not for string instruments)

#### 3.2.2.2.5 Aspects of work space

*Different situations and needs*
At school, the music lesson usually takes place inside a class room where students can have access generally and can be present even when the teacher is dealing with other student's performance, thus hearing the previous student (the duration of the instructor-led session may be related to the quality and or the difficulty of the work that the student has undertaken since the last course). In this way the students can compare the different responses of the teacher to various students and better understand the pedagogical situations. At a conservatoire, the students may even hear the sound of other rooms with other instrument courses. The conservatoire may also provide rooms for chamber music work. A recording studio may also be available to

allow the students to record sessions or make experiments. Further, for self-practice in Practice Training the student has to have access to an adequate space.

### 3.2.2.3 Structural aspects of practice training

The following structural aspects have to be considered in practice training:

- Progression to higher levels
- Integration of different work contents
- Scheduling of work and lessons

#### 3.2.2.3.1 Progression to higher levels

Student progression to higher levels is generally made during an exam by a jury who assesses the work of the year. The teacher may participate in the debate by explaining specific aspects of a student's performance profile.

*(De-)Synchronisation of the evolution of different learning aspects*
A learning curve may be divided into different skills that evolve using different logics. For example technical exercises may be disconnected from work on musical repertoire at a certain time, then synchronised. Also different technical aspects can be separated and united again when working on a certain piece that can unify different skills. These can make important differences among students who can master certain aspects earlier than others. Exams and school concerts are key moments where different cycles and individual paths should be synchronised. This leads to the complex work of monitoring of the student's progression and matching it with the next stage academic program.

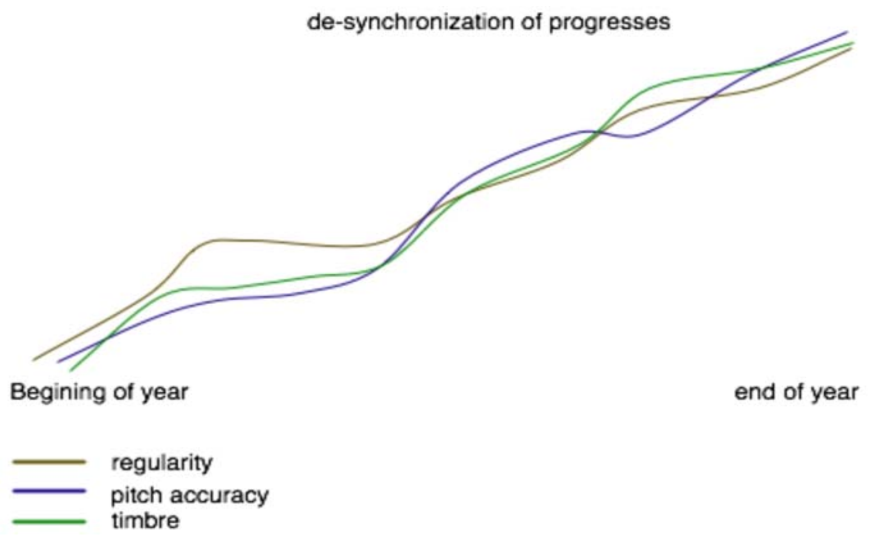


Figure 11: De-synchronisation of music learner's constituent skill acquisition streams over time

#### 3.2.2.3.2 Integration of different work contents

In some cases, a student may work on several pieces. This situation occurs generally for advanced students who can work a lot at home. The teacher often tries to find complementary pieces to avoid the monotony of style. Skills may be similar, with very different pieces, for instance, a piece of Bach with a lot of arpeggios, and a study of Chopin on arpeggios. Several musical skills can be improved in parallel even if they are not the defined learning goal of the current work. The student may continue to progress on skills that he is not specifically addressing, while practicing "adjacent" skills. For instance, if the student encounters a given difficulty, and studies this difficulty for a while without seeing any progress, the teacher may interrupt the work and advance with the piece. Later, the student may return to the specific subsets of the skill where he did not succeed previously and discover that he has somehow gained the ability to succeed in those skill subsets that he was learning previously without success. The monitoring of progression should take these effects into account by allowing the teacher to re-valuate the same assessment several times in random order.

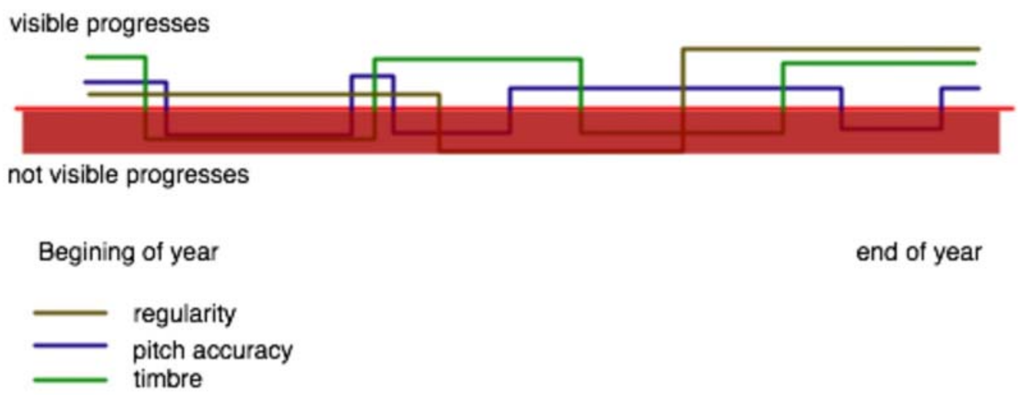


Figure 12: Patterns of foregrounding of assessment of individual skills progress stream over time

#### 3.2.2.3.3 Scheduling of work and lessons

*Lessons with a teacher vs. homework*

The scheduling of work has to accommodate both the constraints of the specific learning curve of the student as well as the scheduling of the exams. The teacher generally makes a program of study over the year according to these constraints. Some exams may allow the student to choose between several pieces at the same difficulty level.

The frequency of lessons with a teacher is typically once a week, but can be at any other frequency. In the interval between two lessons with the teacher, the student is to work by himself according to a work plan established by the teacher, which can have various forms such as a precise schedule of exercises or a set of exercises to be performed in any order, etc.

The schedule of the student has to be constantly adjusted with external parameters such as normal school work, the varying levels of motivation of the student, etc.

*Complementary activities*

Other activities of the students may have great impact on their Practice Training such as exercising with other instruments, orchestra playing or chamber music practice, another artistic practice or even sports.

### 3.2.2.4 General aspects of practice training flow control

Additional aspects of a more general nature that can influence practice training flow control are as follows:

- The degree of multi-modality in receiving and responding to Process Training
- The level of student motivation

#### 3.2.2.4.1 Practice training as a multi-modal process

The learning of a musical instrument involves the development of knowledge, in conjunction with both, mental and physical skills concerning a highly multi-modal activity e.g. neuro-motor-coordinative skills, psycho-cognitive and bio-feedback efficacy etc..

Part of the required skills are generic; concerning basic musical concepts and representations as well as the perception of musical parameters applies to any instrument even if acquired while learning a specific one. Further skills varying from one instrument to another include specific gestures and motor control as well as the perception of specific sound characteristics.

Moreover, Practice Training involves various types of memory training.

#### 3.2.2.4.2 Aspects of motivation and social aspects

The student's motivation can be influenced by various incentives:

- Incentives related inherently to music playing such as the musical repertoire, ensemble playing, public music performance (long term goals)
- Incentives related to everyday practice (to maintain interest and overcome difficulties)
- Social incentives

#### 3.2.2.4.3 Emerging pedagogies and creative interfaces

While traditional pedagogy is preserving traditional methods of music learning, a growing set of music teachers are interested in enhanced pedagogy using new innovative tools. Some of the reasons for such an interest seem to be related to the difficulty in explaining fundamental sound characterisations without them being immediately related to a given aesthetic.

New interfaces based on sensors are sometimes used to avoid this problem by making what may be called "musical metaphors", enabling the study of a musical aspect with a free aesthetic characterisation. A teacher may decide to abstract a given gesture from a piece, and use a sensor based tool to feed this gesture inside another musical process, not related to the original piece.

Such tools may enable the students to concentrate on fundamental musical aspects such as timbre, "breathing" (i.e. arsis and thesis of a musical gesture). The use of these creative interfaces allows an important reflection on the link between sound parameters and gestures. As an example, some experimental tools have been successively used (reported by IRCAM, Paris) to link the energy of a conductor-like gesture tracked by a set of accelerometers and benders with the way a soundfile is played and electronically transformed.

#### 3.2.2.4.4 Creative projects

In some cases, the use of innovative tools in classrooms with groups of students may lead to creative projects. These projects may be done in association with a composer who, with the teacher, will elaborate a musical work for the students, usually played or showed at the end of the academic year. The project may amount to a musical installation, a concert, a CD, and/or a performance.

Most students who have been involved in such projects are usually more curious and open to a large spectrum of different music styles.

As an example, a group of French teachers have recently conducted a project called “Forbidden Planet”. This is the title of a cult science-fiction movie made in 1956 from Shakespeare’s play “the tempest”. This movie is well known among electronic music composers because it is the first to have its soundtrack entirely made of electronic sounds. The students of a number of French public music schools have thus studied the birth of electronic music through this movie. Then they were asked to recompose the music of silent scenes of the movie with sensors linked to musical processes built by themselves during the academic year. Each school working on the same scenes, a lot of different music was collected, and at the end of the year, every school was to give a performance with the sensors in front of the movie, and the best performers were to receive a prize given by an academic jury.

# 4. State-Of-The-Art Online Learning Models

## 4.1 SCORM

SCORM (Sharable Content Object Reference Model) describes a specific way to deliver e-learning content and is part of a strategy called the Advanced Distributed Learning (ADL) initiative. It is a technical specification that enables e-learning to be interoperable, durable, reusable, and accessible. One may develop instructor-led training and deliver it via the Internet. That training would be categorised as e-learning, but it would not be SCORM-compliant.

## 4.2 Introduction

SCORM uses SCOs, Sharable Content Objects composed of assets that launch in a SCORM runtime environment. Metadata enables managers, learners, designers, programmers and others interested in education and training to identify and locate instructional material. A SCO can be for example a segment in a lesson or a lesson in module. A SCO is independent of other instruction, so it cannot rely on other SCOs. They should be small enough to allow reuse above all multiple learning contexts. The SCOs should contain complete instructional content and all assets supporting the instruction. A well designed SCO should serve numerous audiences in achieving multiple outcomes, making it ideal for courses for which it was originally designed.

### 4.2.1 Integration Capabilities with MPEG Applications

The purpose of the Digital Item Declaration (DID) specification is to describe a set of abstract terms and concepts to form a useful model for defining Digital Items. Within this model, a Digital Item is the digital representation of “a work”, and as such, it is the thing that is acted upon (managed, described, exchanged, collected, etc.) within the model. The goal of this model is to be as flexible and general as possible, while providing for the “hooks” that enable higher level functionality. This, in turn, will allow the model to serve as a key foundation in the building of higher level models in other MPEG-21 elements.

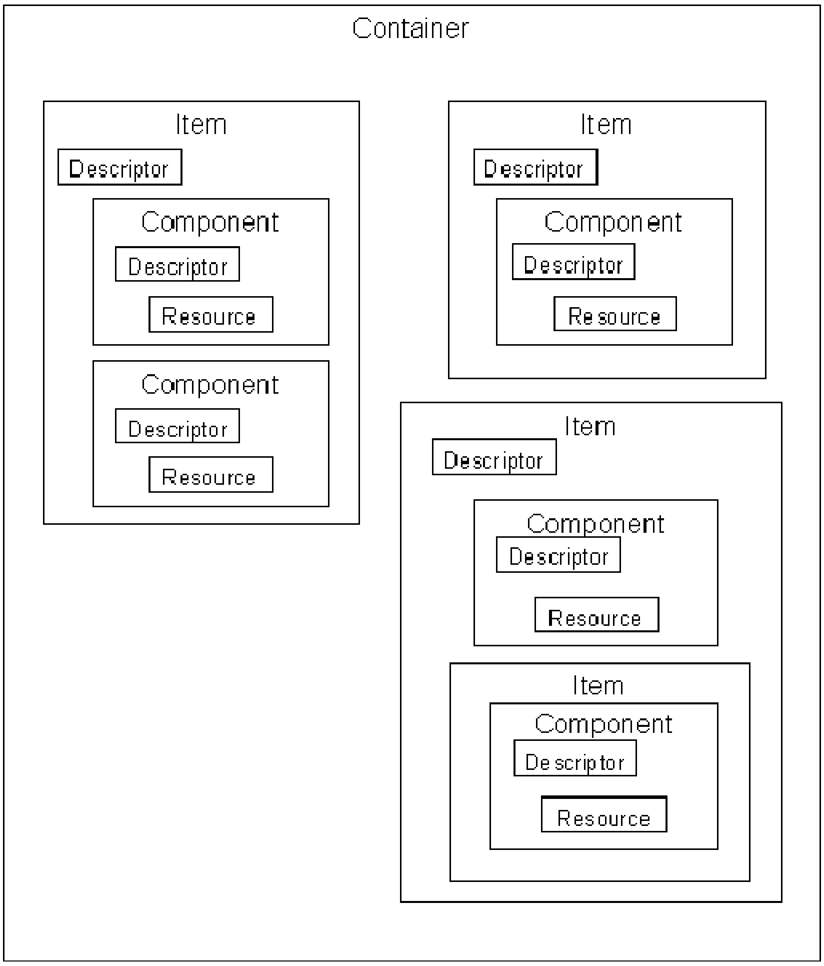


Figure 13: Relationship of the principal elements within the Digital Identification Declaration Model

## 4.2.2 Existing Software Tools and Examples

**eXelearning Authoring**

The eXe project is developing an off-line authoring environment to assist teachers and academics in the publishing of web content without the need to become proficient in HTML or XML markup. The project is funded by a grant from the Tertiary Education Commission of New Zealand and is led by the Centre for Flexible and Distance Learning at the University of Auckland. Export SCORM 1.2, IMS, Web Site and single side possible.

**DotNetSCORM**

The purpose of the DotNetSCORM project is to create an Open Source Learning Management System using .Net technologies. There are currently several SCORM compliant Learning Management Systems written in Java and PHP. These are mostly based upon the ADL Sample RTE. However due to the technologies used they can not be tightly integrated into the Windows Server environment. Therefore the goal of this project is to create a SCORM Compliant LMS to serve as a model for further development and use of the SCORM standard on the Windows Platform.

**Course SCORMPlayer Standard (FREE)**

The Course Player Standard is a SCORM engine implemented on the client side. It automatically provides the navigation and delivery services to the learner by extracting information from the SCORM package. The learner's progress is stored temporarily on the learners' machine. The advanced features implemented in Course Player Standard include:

- Custom layout of your SCORM course based on flexible frameset design (or it can be downloaded as freeware)
- Dynamic SCO look and feel based on the user's style sheet (or it can be downloaded free)- support true re-use of learning objects
- Fully SCORM v1.2 compliant
- Easy creation of CD-based SCORM course. The SCORM course can be expanded into a directory to create a CD with both Course Player and a course for the user. The Course Player will read the necessary information from the SCORM course and create the navigation automatically reduced load on the web server if the Course Player is used as the front end. There is no need for any dynamic scripts on the server to deliver full compliant SCORM courses.

## 4.3 IMS

The "Global Learning Consortium" is a non-profit standards organisation concerned with establishing interoperability for learning systems and learning content and the enterprise integration of these capabilities. Their mission is to "support the adoption and use of learning technology worldwide".

The AccessForAll Meta-data specification is intended to make it possible to identify resources that match a user's stated preferences or needs. These preferences or needs would be declared using the IMS Learner Information Package Accessibility for LIP specification. The needs and preferences addressed include the need or preference for alternative presentations of resources, alternative methods of controlling resources, alternative equivalents to the resources themselves and enhancements or supports required by the user. The specification provides a common language for identifying and describing the primary or default resource and equivalent alternatives for that resource.

## 4.4 EML

In the context of the aims of the first LTSN session (to devise practical strategies for supporting staff in designing online courses), this commentary describes EML and IMS Learning Design, covering their historical development, current use and importance both to staff and educational developers.

The thrust of the commentary will be that the current learning object centric view of the e-learning world should evolve into a learning activity centric view. Here, centre stage is given to the performance of individual and group learning activities designed to attain learning objectives and, in the process, making use of learning objects.

## 4.5 LOM

This Standard is a multi-part standard that specifies Learning Object Metadata. 'LOM (Learning Object Metadata)' is defined as the attributes required to fully, or adequately, describe a Learning Object. Relevant attributes of Learning Objects to be described include type of object, author, owner, terms of distribution, and format. Where applicable, LOM may also include pedagogical attributes, such as teaching or interaction style, grade level, mastery level, and prerequisites. It is possible for any given "learning object" to have more than one set of LOM.

The applicable Standard for LOM is "IEEE P1484.12". The full name of the Standard is: "Standard for Information Technology - Education and Training Systems - Learning Objects and Metadata.

The yet-to-be-finalised standard specifies the syntax and semantics of LOM, and focuses on the minimal set of attributes, needed to allow Learning Objects to be managed, located, and evaluated. The standards will accommodate the ability for locally extending the basic fields and entity types, and the fields can have a status of obligatory (must be present) or optional (may be absent).

## 4.6 Integration Capabilities with MPEG Applications

Within the i-Maestro framework the Symbolic Music Representation (SMR) generation algorithms are to be used for the generation of music material for exercises. SMR enables the synchronisation of symbolic music elements with audio-visual events that are represented and rendered using existing MPEG technology.

The MPEG standards for multimedia representation, coding, and playback, when integrated with symbolic representations of music provides content interoperability and an efficient high quality, peer reviewed, standardised toolset for developers of such products.

The encoding of multimedia content, including various object types and scene description as provided for in MPEG4 would allowing specifying object composition rules and precise synchronisation among multimedia objects and

- Quite a few musical products integrate a symbolic representations of music with multimedia content and tend to have a logical structure consisting of symbolic elements that represent audiovisual events; the relationship between those events; and aspects of rendering those events e.g. Interactive music tutorials
- Play training, performance training, Piano keyboards with symbolic music representation and audiovisual capabilities,
- Mobile devices with music display and editing capabilities.

There are many symbolic representations of music including different styles of Chant, Renaissance, Classic, Romantic, Jazz, Rock, Pop, and 20th Century styles, percussion notation, as well as simplified notations for children, Braille, etc.

•

The i-Maestro Exercise Generator as part of the i-Maestro Production Tools is complementary to the Music Exercise Authoring Tool in providing automated generation of Exercises. The main outputs produced by the Exercise Generator are Music Exercise Formalisations in Training Specification Language (TSL) and Music Notation in MPEG Symbolic Music Representation (SMR), which can be used by the Music Exercise Formalisation. Once a teacher has combined a few pedagogic units, for example a course, this package will be composed by an XML header and by one or more zipped files. Each zip file will contain several types of files including Lesson Metadata, Music Exercise Formalization, MPEG-4 and SMR Segment, representation of music scores, SMR Segment, Assessment Parameters, Context Parameters, Multimedia commands, material (PDF, text, flash, video, audio, etc) needed for the Knowledge Units, etc. The result of the authoring tool is accompanied with a SCORM manifest file in order to link all the available resources. The inclusion of SMR in MPEG and the deployment of SCORM and SMR in I-Maestro will allow MPEG integration

Mpeg integration is now established for SMR which is part of MPEG4 and there is a growing trend towards increasing Mpeg4 integration with respect to all the other standards.

## 4.7 Music Education Paradigms

Computer interfaces must allow users to make and manipulate musical elements without the need for prior training, instrumental skills or the ability to read standard music notation. The issue of notation is an important one. While it is relatively easy for children to generate short musical ideas using whatever materials or instruments are to hand, it is a much more difficult problem to manipulate these on a larger scale so as to confront compositional ideas such as texture, form or structure.

Many younger music students intuitively perceive music in aggregated units (phrases etc) rather then at the formal 'note' level making a notation based approach particularly difficult for them. A well designed computer graphical interface should be able to bypass the notation issue thereby enabling the kind of musical manipulations that might otherwise not be possible.

### 4.7.1 Lazy Learning Approach for Music Learning

Lazy learning is proposed as a promising and alternative model for implementing many types of human behaviour, including music perception and cognition. Lazy learning, which includes instance-based learning, exemplar-based learning, memory-based reasoning, and case-based learning, does minimal work during input of data and defers processing until requested.

Greedy learning, represented by rule-based reasoning, decision-tree induction, and neural networks, on the other hand, tries to learn as much as possible in an architecture that is relatively small, explicitly producing generalisations to solve problems. Lazy learning becomes useful where greedy learning fails. It is particularly applicable to domains in which there are only a few underlying principles and a large amount of exceptions—such as music. The study of music may also give insights into temporal representation, emotional information processing, and creativity.

Exemplar-based model, which is analogous to the idea of "learning by examples," is proposed here as an alternative approach to modelling many aspects of music cognition. Although humans are capable of consciously abstracting concepts and deriving rules, there are other cognitive tasks such as music knowledge acquisition that are largely non-verbal and defy generalisations.

In music, style recognition, harmonisation, expressive performance, instrument recognition, and structural analysis are some of the obvious targets for the deployment of this model.

### 4.7.2 Collaborative Creativity

Traditionally, learning was perceived as the assimilation of concepts presented to the student by the teacher, viewed as providing students with the ability to comment intelligently on the subject domain. In music learning such concepts include musical scales, keys, chords and instrument training. However, from a contemporary perspective, the constructivist paradigm emphasises that learning is most effective when the student is an active participant as opposed to a passive receiver of knowledge. Learning is a social activity in which interactions with others are an integral part of the process. Similarly, creativity also involves the active construction of ideas within social settings. Collaborative creativity can be a route to learning core concepts, and that creativity is an effective form of learning, which requires students to form multiple perspectives of the learning scenario. Thus music pedagogic regimes that can support collaborative learning enable e.g. online learning enable the students to construct their own understandings via a process of social participation in musicality and creative exploration.

### 4.7.3 Constructivist Learning Environment

Constructivism provides both a theoretical foundation and practical opportunity to move towards building constructivist learning environments. A constructivist learning environment (CLE) is a technology-rich, open place where a learner can use a variety of tools and information resources in his pursuit of learning goals and problem-solving activities. Wherein the learner can draw upon information resources and tools to actively construct knowledge generate a diverse array of ideas, develop multiple modes of representation, engage in social interaction, and solve authentic problems.

### 4.7.4 Guidelines for Accessible Delivery of Text, Audio, Images, and Multimedia

Every person learns differently. At its best, online learning allows each user to interact with lesson material in his or her preferred way, relying on their individual strengths while discounting as much as possible their weaknesses. The principles of excellent software design call on developers to work in full knowledge of the range of human skills and limitations. Software designers of teaching materials and activities, in particular, must strive to achieve this high standard.

When a user has a disability, access to learning software may depend entirely on how flexibly that product can deliver its content. Some users may need only to modify the parameters in which media is presented; other users may require entirely different media. Developers who achieve the kind of flexibility that diversity requires will enhance the accessibility of their product.

At a minimum, developers should provide text representations for all media types. This baseline will help address access for many users. That said, it should be noted that users with learning disabilities benefit from graphical presentations. For this reason, the practice of providing text-only content as an alternative to inaccessible multimedia content may not be an effective solution for users with cognitive disabilities. A number of resources that address flexible media delivery are currently available. The W3C's Web Accessibility Initiative provides accessibility guidelines for W3C technologies such as HTML, XML, SMIL, CSS & SVG. It also provides more general guidelines for web content accessibility, authoring tool accessibility, and user agent accessibility.

### 4.7.5 A SCORM SCO and Content Package/Organisation

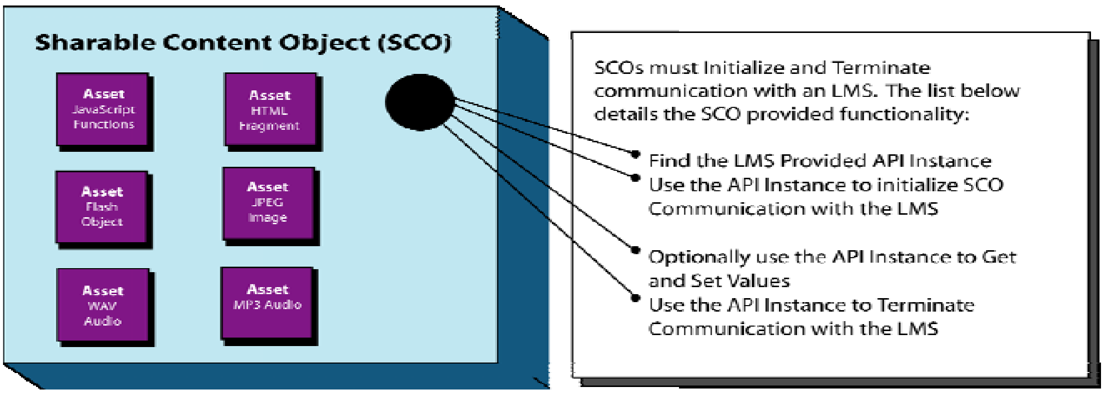


Figure 14: Conceptual Makeup of a SCO

A SCO must have a means to locate an LMS provided API Instance and must invoke the minimum API methods (*Initialize*(“”) and *Terminate*(“”) ).

There is no obligation to invoke any of the other API methods as those are optional and depend upon the nature of the content.

The requirement that a SCO must utilise the SCORM RTE yields the following benefits:

- Any LMS that supports the SCORM RTE can launch SCOs and track them, regardless of who generated them;
- Any LMS that supports the SCORM RTE can track any SCO and know when it has been started and when it has ended; and
- Any LMS that supports the SCORM RTE can launch any SCO in the same way.

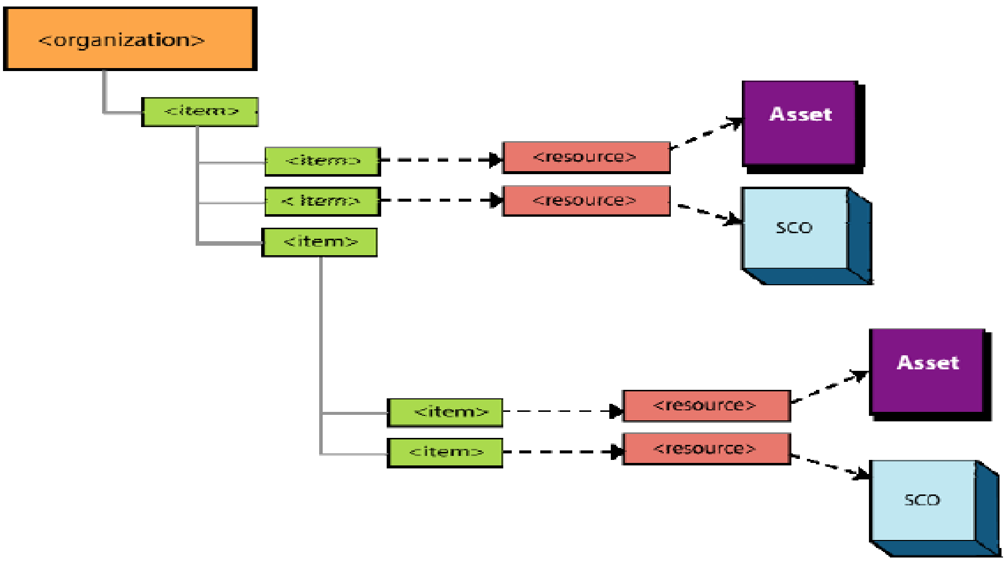


Figure 15: IMS Content Hierarchy Terminology

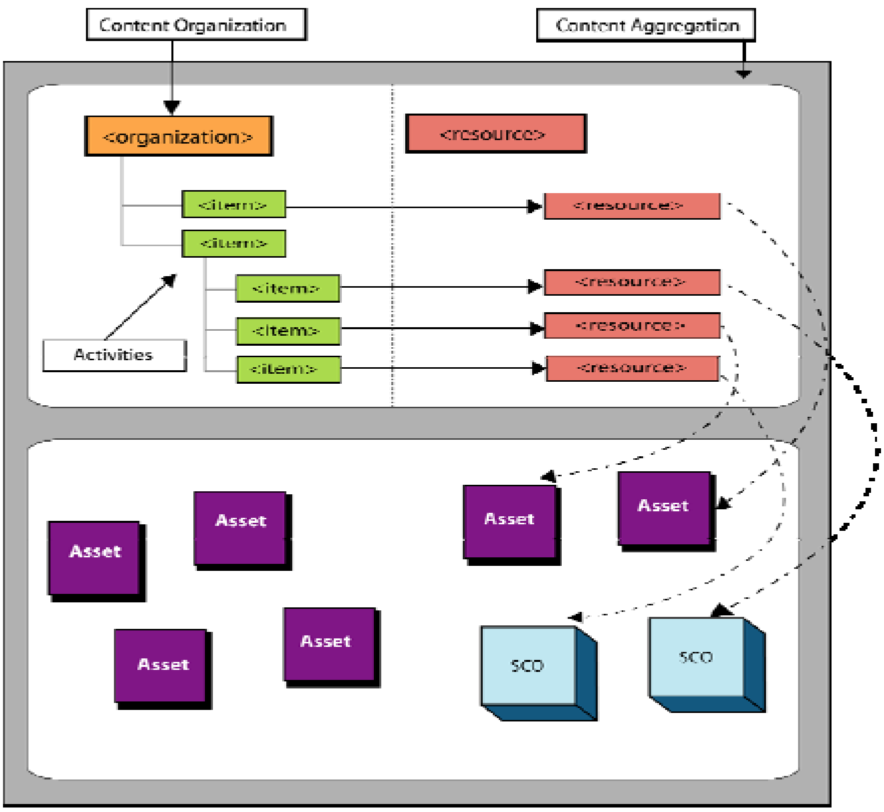


Figure 16: Conceptual Illustration of a Content Organisation

A Content Package, in general sense, bundles content objects with a content organisation that is described in a manifest.
A SCORM Content Package may represent a course, lesson, module, or may simply be a collection of related content objects.
I-Maestro Courses or Lesson Packages should also represent this information required from the SCORM Content package.

### 4.7.6 SCORM Model in I-MAESTRO

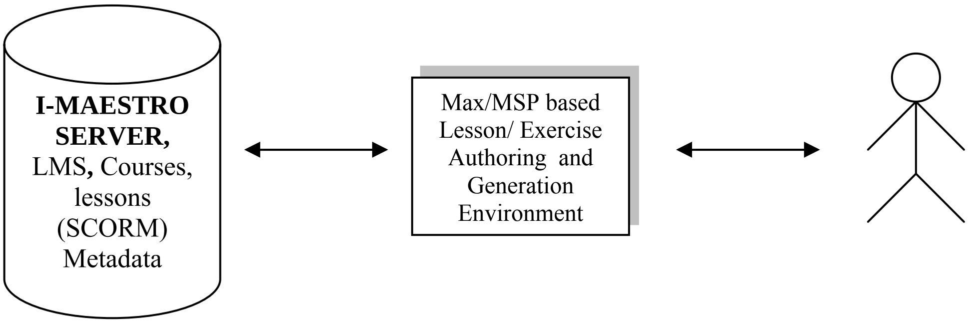


Figure 17: i-Maestro sub-systems in interaction with the student online

The term "LMS" is now being used as a superset description of many content and enterprise management capabilities. Within SCORM context, LMS implementations are expected to vary widely. SCORM focuses on interface points between content and LMS environments and is silent about the specific features and capabilities provided within a particular LMS.

In SCORM, the term LMS implies a server-based environment in which the intelligence for managing and delivering learning content to students resides. In other words, in SCORM, the LMS determines what to deliver and when, and tracks progress and performance as the learner moves through the learning content.

SCORM supports the notion of learning content composed from relatively small, reusable content objects aggregated together to form units of instruction such as courses, modules, chapters, assignments, etc. By themselves, content objects have no specific context. When combined with other instructional content objects, the aggregation provides the context and supports a defined learning experience. Content objects can thus be designed for reuse in multiple contexts.

This approach means that content objects do not determine by themselves how to sequence/navigate through an aggregation representing a unit of instruction. Doing so would require content objects to contain information about other content objects within a content organisation, which would inhibit their reusability by limiting their use to one specific context. Instead, sequencing and navigation is controlled by rules defined within the aggregation and interpreted by the LMS. The LMS merely processes the externally defined rules and itself has no knowledge per se about how the content is organised except through the interpretation of rules defined in the content organisational structure.

This allows the instructional content designer/developer to specify sequencing rules and navigation behaviour while maintaining the possibility of reusing learning resources within multiple and different aggregation contexts. Thus by keeping the rules and navigation separate from and outside of content objects, the content may be reused in new and different ways to support many different instructional strategies.

# 5. State-of-the-Art Authorware for I-MAESTRO

## 5.1 Comparison Max/MSP/ Macromedia Authorware

### 5.1.1 Introduction

At the 1st specification workshop in Florence 24 February 2006, the i-Maestro Consortium decided on the authoring software to be used to provide the underlying multimedia editing functionalities for the i-Meastro Autoring Tool.

After an intensive discussion and filling out the comparison table (see -> 5.1.2 below) the i-Maestro team voted for the Max/MSP Software. An additional reason for using Max/MSP is that most Universities within the consortium already use this software and this would mean fewer licences would have to be purchased.

### 5.1.2 Comparison Table

| Feature | Solution 1: Authorware plus some LMS | Solution 2: MAX/MSP plus/JITTER some LMS |
|---|---|---|
| | | |
| **School Server aspects** | Breeze is very expensive and not open source,<br>MOODLE is open source, based on PHP and MySQL | Breeze is very expensive and not open source,<br>MOODLE is open source, based on PHP and MySQL |
| **SCORM ADL capabilities** | YES: Authorware supports common courseware standards, such as AICC and ADL SCORM version 1.2. (from http://www.macromedia.com/cfusion/knowledgebase/index.cfm?id=tn_19393 ) | NO: this implies that a SCORM external module will have to be developed to load SCORM information of the lesson from a patch. The same SCORM (lesson information) can be used for managing the lesson in the School Server. |
| **Distribution of lessons, download** | YES: Distributing the Authorware Web Player (from http://www.macromedia.com/cfusion/knowledgebase/index.cfm?event=view&id=KC.tn_16696&extid=tn_16696&dialogID=25593634&iterationID=1&sessionID=48304aafb80b251c6934&stateID=0+0+25599560&mode=simple) | YES, once having the SCORM |
| **Managing student profile** | ……………….. | NO to be done manually, YES if a SCORM model is added, etc…additional modules will have to be added by the |

| | | |
|---|---|---|
| | | Authoring tool developer to cope with student profile, assessment status, etc. |
| **XML format support** | YES: XMLParser Xtra added support for XML in Authorware 6.0. XML files can be read and parsed by the Xtra, but not directly imported from the File menu. | YES |
| **Protection** | NO, the code can be saved in a non editable manner | NO, the code can be saved in a non editable manner |
| **DRM support** | NO | NO |
| **Student profile and history management** | YES for both | NO to be done manually, YES if a SCORM model is added,<br>etc…additional modules will have t be added by the Authoring tool developer to cope with student profile, assessment status, etc. |
| **Operating system Call** | YES | YES |
| | | |
| **Programming, Authoring, coding of lesson** | | |
| **SCORM ADL capabilities** | YES: Authorware supports common courseware standards, such as AICC and ADL SCORM version 1.2. (from http://www.macromedia.com/cfusion/knowledgebase/index.cfm?id=tn_19393 ) | NO: this implies that a SCORM external module will have to be developed to load SCORM information of the lesson from a patch. The same SCORM (lesson information) can be used for managing the lesson in the School Server. |
| **Logic structure definition: menu….** | YES | YES |
| **GUI definition: customisation of the user interface for the lesson, for the end user, pupil** | YES | YES Very rich |
| **User interactivity facilities, customisation of the shape of the buttons, of the elements to be manipulated, etc.** | YES | YES Very rich |
| **GUI definition: customisation of the programming environment, graphic/visual** | YES, the authorware provides support for creating wizard for producing the | YES Very rich. A model for creating lesson wizard has to be created by the Authoring tool |

| | | |
|---|---|---|
| **programming** | lessons. They are created by using Authorware. The semantic of the visual programming is mainly flow chart | group in the project. The authoring tool of MAX is mainly based on Event/data Driver semantic. A new model has to integrated may be enforcing the flow chart diagram. |
| **Plug in (external module call) capabilities** | YES, via the Xtra objects | YES |
| **Active X support** | YES | NO:<br>Presently they are working on providing the possibility of activating Active X from Java Script. |
| **Java Script or scripting support** | YES | YES, but the Java cannot be used to make drawings on the screen |
| **Mathematic features/capabilities for the assessment** | YES | YES rich available libraries |
| **Active objects, they are DLL** | YES | YES Many inbuilt components, rich libraries (especially for music and audio related applications) |
| **Lesson Unit Definition and reuse, they are templates** | YES | MAX/MSP “abstraction” mechanism and general persistency features |
| **Drag and drop** | YES | YES |
| **Built in navigation, next page** | YES | YES Primitives available |
| **Specifying connections from consecutive lessons** | YES it can be done | YES, chains of patches |
| **Built in data tracking, how to track at which point you are in the lesson** | YES | YES Primitives available |
| **Custom Buttons** | YES | YES |
| **Automation Support** | No | YES Primitives available |
| **Batch media handling** | YES | YES |
| **Batch media property editing** | YES | YES Primitives available |
| **Collaborative development** | No | YES Primitives available |

| | | |
|---|---|---|
| **Search** | YES | YES |
| **Autosave** | No | YES |
| **Interaction: fill text** | YES | YES |
| **Interaction: Multiple choice** | YES | YES |
| **Interaction: true/false** | YES | YES |
| **Interaction: Slider** | NO | YES |
| **Interaction: piano keyboard GUI** | NO | YES |
| **Database: ODBC** | YES | NO |
| **Database: MySQL** | YES | YES: with an external library of IRCAM |
| **Database: SQL** | YES | YES |
| **Hyperlinks** | YES | YES Primitives available |
| **Package of the lesson** | YES: in binary not editable format or in SCOMR | In EXE not editable format, plus a directory with the DLL and other files |
| **Mouse facilities** | Active X object, events on the screen area are redirected to the active X | The engine communicate to the player the position and events of the mouse |
| | | |
| **Model** | | |
| **Logic definition of the lesson** | YES | YES Very rich set of functions and primitives |
| **Annotation from the student side** | Yes  it has to be coded | YES Primitives available |
| **Metadata modelling and usage** | YES | YES |
| **Packaging** | YES, it has different manners of making a package mainly a SCORM zip, or a protected Authorware file plus many directories and data files. | YES, the Patch may encapsulate the digital resources. An executable version of a max file consists of a directory with a non editable max file (mxp extension) and many DLL, and PAT files. |
| **Managing student profile** | YES | YES Primitives available |

| | | |
|---|---|---|
| **Accessible/open Lesson format** | YES | YES |
| **ZIP support** | YES with external module | YES with external module, may be invoking operating system facilities |
| | | |
| **Player** | | |
| **Multitasking of activities including parallel execution of plugins** | YES, independent from internal and external tasks in plugins | YES |
| **Rendering from the plug in into the screen of the application, autonomously** | YES via the Active X model, a proof of concept has been done with 4 independent Active X running autonomously | YES A proof of concept has been carried out. |
| **Audio play support** | YES (AIFF, AIF, MP3, PCM, SWA, VOX, WAV, WAVE) | YES (QuickTime) |
| **Audio visual rendering support** | YES | YES Extremely rich |
| **Audio processing support** | No | YES Extremely rich |
| **Audio real time input** | No | YES |
| **Audio record** | No | YES |
| **Audio Plug in standard Support such as VST** | No | YES |
| **Audio Streaming** | YES for MPEG3, get connected with a server to get a stream | YES with an external module |
| **Video play** | YES  (AVI, MOV, MPEG, WMV) | YES (QuickTime) |
| **Video real time input** | No | YES |
| **Video record** | No | YES |
| **Video processing support** | No | YES |
| **DVD player** | YES with external tool | NO |
| **Image support: rendering and manipulation** | YES (BMP, EMF, GIF, JPEG, JPG, LRG, PICT, PIC, PNG, PSD, TGA, TGA, TIFF, TIF, | YES |

| | | |
|---|---|---|
| | WMF) | |
| **Image processing support** | YES | YES |
| **Image Printing** | YES | YES (it can print the whole screen of the PAT file) |
| **MIDI Support: play and save** | YES via Active X | YES |
| **MIDI real time input** | NO | YES |
| **Piano Roll model and rendering** | NO | YES: in a separate window |
| **Text Support: rendering in TXT, metadata rendering** | YES (also RTF Support) | YES |
| **Text Processing** | YES | YES |
| **Text to Speech** | YES | YES with an external module |
| **HTML support** | YES | YES external libraries, in addition they are also working on that. |
| **XML Support, with style or not** | YES | YES external libraries |
| **Multilingual support** | ………………. | YES Primitives available |
| **Search Support on text included** | YES | YES |
| **PDF Support** | YES Via Active X | YES, through QuickTime (interactively programmable within MAX/MSP!) |
| **PS Support** | YES Via Active X | YES external libraries |
| **SVG Support** | YES Via Active X | YES |
| **MS DOC Support** | YES Via Active X | No |
| **3D Support, OPENGL** | YES with external module | YES, very interactive |
| **Animation Support** | YES (SWF, GIF, FLC/FLIC) | YES |
| **Posture and gesture support: in/out** | NO | YES |
| **Gesture visual rendering** | NO | YES very rich |
| **Portability: WIN, MAC, LINUX** | YES ( Win & Mac but not Linux) | YES WIN, MAC |

| | | |
|---|---|---|
| **Communication support** | ……………….. | YES Network primitives available (TCP, UDP, OpenSound Control) |
| **Cooperative Support** | NO | NO |
| **Chat support** | NO, Yes via Breeze only | No |
| **File sharing support** | NO, Yes via Breeze only | No |
| **FTP support** | YES with external module | YES |
| **Desktop sharing** | NO, Yes Via Breeze only | No |
| **Integrable in a WEB page** | YES | No |
| **Synchronisation of multimedia, support** | YES | YES |
| **Synchronisation and scheduling of events and actions** | YES | YES Very rich set of primitives and functions |
| **SMIL support** | ……………….. | YES external libraries |
| **Accessibility feature such as screen reader enabling** | YES (Minimal) | YES (Minimal) |
| **Accessibility feature such as short cuts for accessing to the user interface** | YES | YES |
| **SMR Support: rendering and manipulation** | No | No |
| | | |
| **General aspects** | | |
| **Market coverage** | Macromedia – widespread | MAX – widespread in music technology |
| **Cost of player** | 0$ | $0 |
| **Cost of authoring tool** | 3000 euro | $850 including Jitter, without is 495$ |
| **Cost for each authored tool** | Royalty free | The distribution of Patches is free.<br><br>(for business) In Windows you have to pay one shot fee of 1000$ to redistribute packages that include the run rime and |

| | | |
|---|---|---|
| | | the patch.<br>This is constraint is not present in MAC. |
| **Costs of additional Tools** | ……………….. | 395$ for JITTER (video 3D support), see above |
| | | |
| | | |
| **Additional** | | |
| | | |
| **Developer support** | Developer centre | Strong online community |
| **Java integration** | | YES |
| **Developer community** | YES | YES Very active, especially concerning interactive music, audio and video |
| **User community** | YES | YES Very active, especially concerning interactive music, audio and video |
| | | |

## 5.2 MAX/MSP

Max was developed by Miller Puckette at the Institut de Recherche et de Coordination Acoustique/Musique (IRCAM) in Paris in the mid-1980s, as a computer language for the control of a digital synthesizer. It was later adapted by David Zicarelli to manipulate MIDI data and released as a commercial product. MAX/MSP is a graphical programming language. This means that the development of objects is quite easy and you can start programming from scratch at once.

### 5.2.1 Introduction

Working with MAX/MSP is developing applications graphically by using objects, which will appear on the screen as boxes that contain either text or icons. Objects are connected together to create a working program.

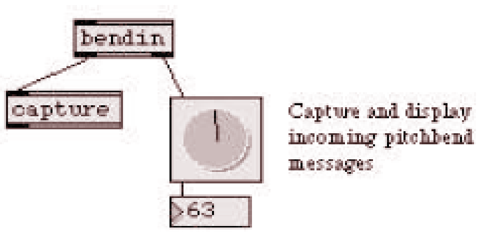


Figure 18: A simple program written graphically using MAX/MSP

MAX/MSP has about 200 different objects (and MSP adds about 200 more for audio processing, and Jitter adds an additional 140 objects for matrix and video/image processing), each of which performs one or more specific tasks. In addition, MAX/MSP provides the facility of programming so that new objects can be created, saved and then used as objects inside other programs that are written.

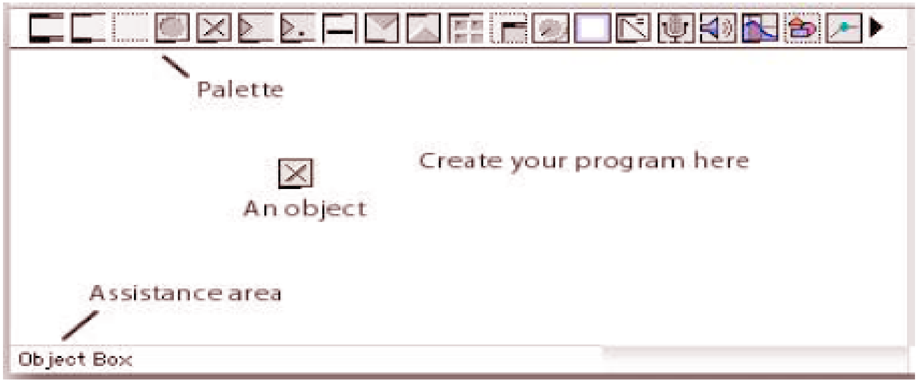


Figure 19: MAX/MSP Visual Programming Interface

### 5.2.2 Support for Learning Models

External JavaScripts have to be written to expand the possibilities of MAX/MSP for the I-Maestro project. There are two Kinds of MAX/MSP Objects:

**Built-in** objects are part of the MAX/MSP application.

**External objects** are separate files that contain e. g. C code that can be “linked into” the MAX/MSP environment in such a way that it is impossible to tell that the code was not part of MAX/MSP in the first place. That is why it is rarely mentioned whether any particular object is a built-in or an external.

In addition, there are two kinds of MAX/MSP objects:

- Normal objects—MAX/MSP objects that appear in a Patcher window as an object box that contains its name or a character (e.g., borax, &&)
- User interface objects—MAX/MSP objects that appear as icons in the Patcher window palette and have some distinctive graphical appearance in a Patcher.

Accessing the functionality of Java externals in a MAX/MSP patcher is slightly different to accessing the functionality of a MAX/MSP external written in C. C externals are loaded directly into the MAX/MSP application environment at runtime, but Java externals are loaded into the MAX/MSP environment and thereafter communicate with the MAX/MSP environment through a proxy external object called *mxj*.

For instance, if an external is named "*myextern*" written in Java, the functionality of "*myextern*" in your Max/MSP patch is accessed by entering the name of the external as an argument to the *mxj* object: instead of typing *myextern* into an empty object box as if the external had been written and compiled in C.

*mxj* is a MAX/MSPexternal written in C that interacts with an instance of the Java virtual machine (JVM) within the MAX/MSP application environment and provides the glue that allows calls from MAX/MSP to be dispatched to your Java code through the JVM and vice versa.

# 6. Towards Reference Architectures for Dynamic Pedagogic Flow Adaptation in Blended Learning with PCK-empowered MaestrOnto-SCR: the i-Maestro Pedagogic Material Generation and PFlow Control Support TSL Framework

## 6.1 PCK-empowered Mediating representations for Pedagogical Knowledge Elicitation and Modelling

In this section we motivate the semantic-associative Pedagogical Content Knowledge (PCK) representation as a rich, open and dynamic pedagogic unit representation framework. This is to reflect the fact that teachers experientially augment their understanding of the inter-relationships between topics, through what are termed emerging pedagogical relationships (P-Rs), i.e. the relationships above and beyond those recognised by all domain experts. We explore the nature of the framework that is required in order to support the representation of the underlying psycho-socio-cognitive phenomena and the semiotics that naturally influence the dynamically evolving and maturing pedagogical processes.

We introduce a minimum of three ontological network abstraction layers to support the unfolding pedagogic delivery flow that is ultimately uniquely instantiated at any given instance of pedagogic experience. In the framework, the first layer (Pedagogical Domain Layer) is an abstracted representation of the pedagogic domain (e.g. as a taxonomic subject structure). The second mediating layer (PCK Relationships Layer), acting on the first layer, is intrinsic to a given practitioner. The third layer (Pedagogic Flow Enactment Layer) represents how pedagogic experience unfolds through the instantiation of evolved P-Rs. In this layer P-Rs are personalised from the viewpoint of the teacher as well as responsive to the pedagogical delivery context through appropriate invocation of representations, contingent and spatio-temporal ordering and dynamic augmentation by the teacher and the student. We highlight some examples of the P-Rs that can be accommodated by a PCK to support dynamically responsive pedagogic flows and thus conclude that a PCK-empowered representation architecture is well placed to support the enhancement of the mutual pedagogic Quality of Experience (QoE) along with the evolution of personal pedagogic development for both teacher and learner thus supporting a virtuous cycle of continuous evolutionary enhancement of Pedagogic QoE and outcomes.

One cannot hope to technologically reproduce every aspect of the proactive, pedagogical engagement of a good teacher. Indeed, since such teaching relies in some part on a complex human relationship between the teacher and the student, one is ill-placed to attempt to emulate it; but such a privileged relationship is of course to be facilitated as best as possible with the aid of technology-enhanced multi-modal engagement of both sides as it occurs in blended learning approaches to pedagogic management. In these an appropriate eclectic mix of teaching interactions, spaces, content, media and tools can be deployed to achieve the learning objectives. Thus in blended learning, technology is seen as being possibly useful in *supporting* face-to-face teaching, enabling students to interact with learning material in their own time and place, i.e. asynchronous study outside the constructivist tutor-assisted teaching sessions.

Designing any subject learning material requires choice-making on the part of the teacher. Although strongly influenced by commonly held concepts, skills and representational forms, teachers would invariably, perhaps implicitly, orientate the learning material according to their own respective ways of seeing the subject and their own *patterns-of-relating* to various pedagogic norms. However, an experienced teacher's view of how s(he) wishes students to envision a particular topic may well depend on the particular pedagogical context; e.g. upon the students' pre-knowledge and particular learning objectives. Therefore, the questions arise as to whether a teacher's experientially derived, flexible and for ever evolving view of a subject topic can be modelled and whether such a model can be technologically implemented.

Obviously subject knowledge is vital to teachers, but teachers, themselves as learners, must gain knowledge of how to conceptualise a topic for their students, how to understand it pedagogically, make sense of it for the classroom, and ultimately, how to teach it. That layer of the teacher's knowledge which is above and beyond knowledge of the subject has been termed Pedagogical Content Knowledge (PCK) [5].

There are differing opinions as to the nature of PCK, but the prevailing view would maintain that PCK is formed through teaching experience and relies on adequate subject-matter knowledge, [6]. Although PCK must incorporate practical teaching skills, such procedural knowledge must draw upon a teacher's personalised pedagogical view which in turn is derived from acquired subject knowledge. Therefore modelling PCK requires the consideration of declarative as well as procedural aspects. Shulman (1987), [7], and others have considered that PCK involves "…the structures of subject matter, the principles of conceptual organisation and enquiry".

For an experienced teacher who would have the ability to "see" a topic pedagogically, PCK is the tacit encoding of the pedagogic delivery knowledge experientially acquired through their career and which incorporates the ontological/ taxonomic knowledge of the subject domains taught, plus heuristic, strategic and tactical knowledge of how best to teach any part of the subject, what possible cognitive bugs or learning difficulties to expect relating to the assimilation of any part/concept by which types of learner in which delivery contexts and how best and when to assess and/or fix such learning problems and generally how best to maintain dynamic pedagogic flows that are maximally invitational, motivational, stimulating and above all remain constructively engaging.

Therefore, if we were to consider how to model the knowledge from which an e-learning system might draw its information for delivery to a student, it would be naïve to suggest that such knowledge is purely subject oriented. The tutor does not have a set of techniques which are then applied to a bag of topics; the techniques are tied into those topics. Pedagogical relationships tend to be purposeful. Topics are related for a reason. That is, an experienced teacher naturally operates beyond the standard whereby say a novice teacher with some general teaching skills might initially just use the bare subject content; the experienced teacher integrates teaching skills with the subject content, and therefore in turn flexibly re-interrelates subject content for pedagogical purposes. Indeed some authors have argued that the whole concept of PCK as a separate knowledge domain is redundant. PCK itself is seen by them as just another aspect of the subject itself [8]. According to Kinach (2002), [9], a given PCK, as developed for a taught subject, would include knowledge of the relationships between pedagogical concepts and concepts within the taught subject.

Semantic-associative frameworks have been found to be useful in representing declarative knowledge of a subject domain at a particular level of abstraction. A familiar form motivated by the Topic Map standard [10], offers scope for a powerfully expressive representation of Pedagogical *patterns-of-relating* (P-Rs). Obviously representing such P-Rs can usefully enable the matching of the pedagogic flow to the situated learning conditions through allowing appropriate dynamic instantiations to best exploit the relationships amongst elements of concepts, topics, delivery context as well as the interplay of influences between semiotic structures. If such representational forms were to mediate the *exchange of actionable pedagogic insight* between subject specialists, or even amongst students, as communities *of practice*, then they must clearly represent the declarative pedagogical (best) practice, knowledge, at least as seen by some practitioners, for the particular subject. Thus it could be argued that technologically-based pedagogical systems must be enriched with an appropriate modelling of the *personalised* knowledge of the tutor as afforded by PCK.

It has been argued [11] that semantic-associative frameworks representing shared ontological knowledge may be augmented and hence personalised by declarative aspects of a teacher's PCK. This augmentation may be represented by introducing into a topic map *new particularised and purposeful pedagogical relationships*; applied to the music pedagogy domain as an exemplar. However, compared with the association vectors within a shared ontological topic map, these additional pedagogical relationships are distinguished in carrying operational and experiential information regarding their *purpose* within a particular pedagogical unit, e.g. the role of a lesson or a unit in a particular situated pedagogic delivery context.

### 6.1.1 Semantic-Associative Representation of both Experiential and Expert Pedagogical Knowledge

With the advancement of the use of shared content objects, there is a risk that the e-learning aspect of blended learning will only encapsulate bare subject knowledge; and so it may be denuded of the teacher's insight into the subject and their empirical experience of its optimal situated pedagogic delivery modalities. Although e-learning cannot but augment face-to-face teaching from an expert teacher, it should not merely become an inflexible, rigidly instructivist tool, modelling a linear pedagogical discourse focused on the delivery of mere subject facts. Our research here considers an e-learning architecture which moves away from a behaviourist, reductionist, subject-only paradigm, towards a deeply constructivist, holistic, pedagogical-subject paradigm. It is important to note that our advocacy of blended learning is motivated by this commitment to a pedagogically purposeful variation-theoretic constructivist, rather than instructivist, approach with a healthy level of learner autonomy such that it would best enhance learning outcomes and encourage learner-teacher collaborative engagement. As Oliver and Trigwell [12] have pointed out, without variation there is no discernment, and without discernment there is no learning.

Learning is more likely to become constructively purposeful, if pedagogical knowledge is represented and expressed such that the rationale for alternative pedagogic delivery pathways and choice-making is mutually transparent, accessible and thus open to negotiation and refinement by interested parties in the light of experience.

In the classroom there are many different pedagogical approaches which seem not to have been fully considered within e-learning. An experienced subject teacher may wish the students to begin by having an opportunity to have a view, at an appropriate abstraction level, of the structure of the whole subject domain, before helping them along to understand one particular part. Such a teacher will often personalise the subject knowledge through giving students explanations of how s(he) understands or, perhaps first managed to get into grips with a particular aspect of a (sub)topic. A teacher may well introduce a wealth of different ways of representing concepts within a subject, often making use of analogues, metaphors, over-emphasis or selective focus techniques to convey the point at a particular moment. Such a teacher, has in effect developed an organic network of domain and pedagogical knowledge which may be adapted to many different situations. Such a network with its relational understanding is, according to Barwell (2000), [13], one aspect of the very idea of understanding.

This insightful, pedagogical view of the subject with its rich tapestry of inter-relationships cannot be modelled merely through a structure composed of shared learning objects. Although the deployment of such a structure usually exploits a highly interactive delivery system, there is still a missing dimension. We argue here that this missing dimension is an aspect of PCK; namely the flexible, declarative pedagogical relationships between shared learning objects. The Topic-Map-enabled representation of such relationships confers significant operational advantages re the dynamic maintenance, tractability and merging of representations. This is obtained through the efficient and expressive features of this XML-based open standard as outlined in the next section. A schematic of the abstraction spaces of a PCK-empowered Pedagogical Knowledge Representation Architecture appears as in figure below.

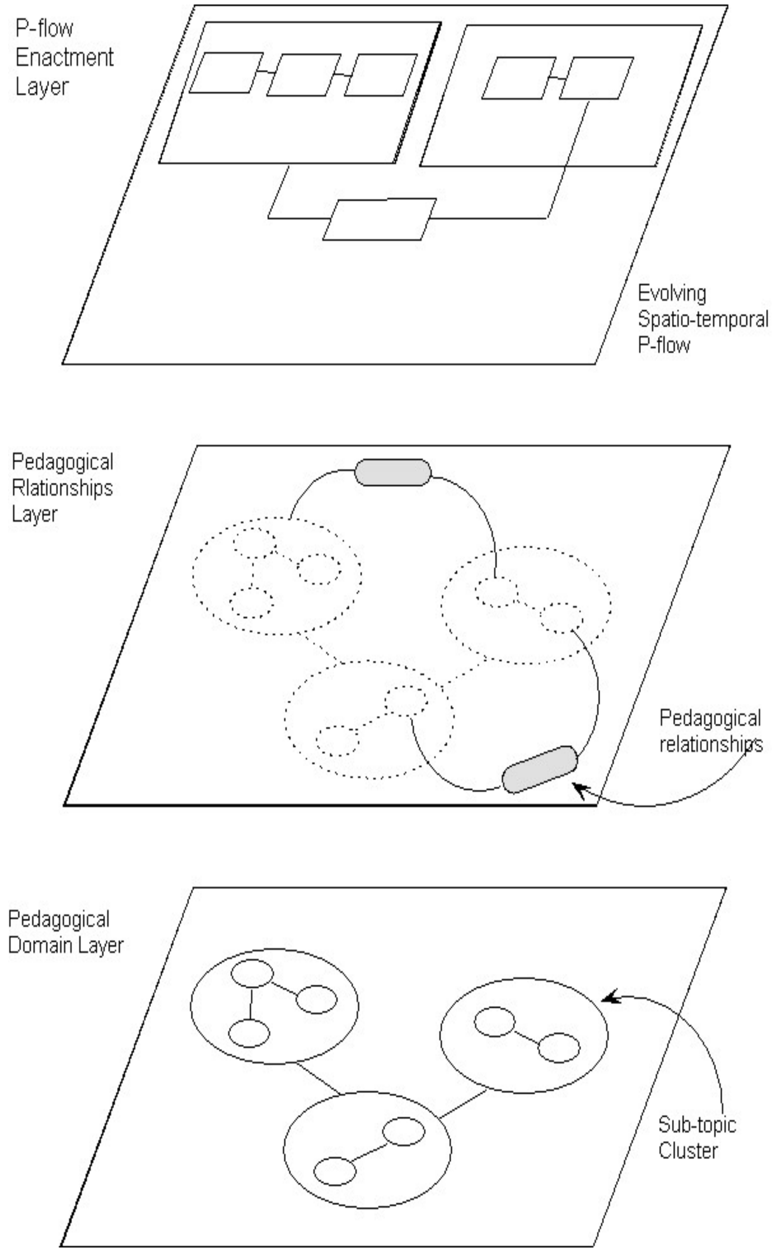


Figure 20: Schematic of the abstraction spaces of a PCK-empowered Pedagogic Representation Architecture

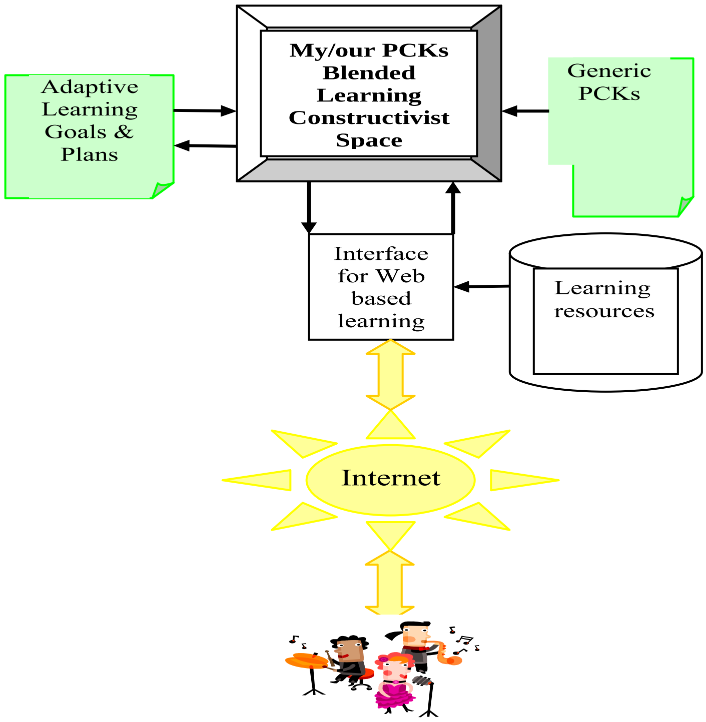


Figure 21: A PCK-mediated managed blended learning framework for group or solo learners.

### 6.1.2 PCK Deployment

The use of PCK to mediate blended learning fits well within the existing e-learning content interoperability framework as PCK deployment is based on open content. SCORM (Sharable Content Object Reference Model) [14], describes a specific way to deliver e-learning content such that it is re-useable, shareable, durable and accessible. In operational use the PCK-empowered framework will deploy such pedagogic Shareable Content Objects (SCOs) as available for the teaching domain and incorporates them within the PCK network thus adding the personal pedagogical knowledge which associates the objects with the declarative pedagogical knowledge for optimal personalisation of the learning experience and the most effective situated delivery for a particular learner. The proposed representation thus remains fully SCORM-compliant as well as IMS-compliant. However SCORM does not address the issues of how to make effective e-learning, nor does it describe or prescribe what makes, or how to make, good SCORM content. The augmenting of SCOs so as to enable a personalised teaching and learning experience is what motivates the PCK-empowered environment. As for IMS since its specifications too promote the reuse of e-learning content [15], therefore full interoperability with both SCORM and IMS is assured.

### 6.1.3 Pedagogical Relationships Representation

Effective teachers are required to make complex pedagogical decisions in the classroom, in order to provide possible routes for their students to understand ideas, build concepts and acquire related skills i.e. stimulate their cognitive and/or skills (meta) scaffolding, creativity and generally personal development and self-actualisation e.g. in music education this may amount to co-architecting a learner's progression from zero tonality, as an absolute beginner, to intermediate or advanced level musical expressivity [16]. Thus for teachers to be proficient and play their vital role, they must acquire the following salient and mutually supportive elements of expertise:

**i)** Appropriate and sufficient content knowledge
**ii)** General pedagogical knowledge
**iii)** Dynamically evolving subject-specific PCK

However, there are many factors which will affect the pedagogical process, not all of which are under the teacher's direct control. The effective teacher would enhance and adapt their PCK in response to some of these uncontrollable changes.

Of course, as with other human knowledge, PCK is complex, but, despite this complexity, there are aspects of PCK which may be modelled as either declarative knowledge, procedural knowledge or possibly inferential relationships between the two. Deciding on whether to emphasise the declarative or procedural aspects of the teacher's PCK will depend upon whether we wish to stress the characterisation of epistemology as *knowing that* or *knowing how* [17].

The professional subject specialist and subject teacher both develop their own, personalised conceptual knowledge base. But unlike the professional subject specialist, the teacher must structure their knowledge base not just for their own understanding, but for that of their students. To be able to teach students possessing a wide range of abilities and foundational knowledge, an effective teacher must have PCK which is rich in the use of descriptive models, pedagogical methods and relationships. Of course, the effective teacher must develop a learning environment in which all types of student may acquire their own concepts and develop skills. The teacher's PCK will influence how they design activities, e.g. semi-structured teaching and assessment components, as well as how they represent the taught subject as a whole. Mizoguchi and Kitimura (2001), [18], found that teachers' subject knowledge influenced the way they represent their subjects to their students. Since the effective teacher would use a wide range of different representations to cater for the different types of student, it follows that such a teacher must have a rich understanding of the taught subject mediated through diverse representations. Without sufficient care, a particular way of representing a concept (e.g. in terms of content, modalities and/or timing) instead of being an aid to the student's understanding, becomes a hindrance. An effective teacher's PCK is fully cognisant of what and when re-enforces which situated learning and what would detract from, confuse or inhibit the learner's assimilation including the whole spectrum of interventionist and non-interventionist steps whether applied to teaching or assessment phases.

Indeed creativity is a sub-process deeply instrumental in learning according to Truman Mulholland, Badii, [2], and creativity-theoretic considerations imply a natural latency requirement (Dynamic Natural Latency Window, DNLW) for incubation and maturation of ideas, as e.g. may be required for fine-tuning of neuro-motor skills in learning to play an instrument. Thus an experienced teacher may adopt a tactical non-interventionist approach, e.g. avoiding pre-mature assessment of certain aspects of a learner's assimilation of facts and skills for which a pedagogic response may be best deferred to a later stage so as to allow the natural, "off-line"/online, cognitive scaffolding to grow and crystalise its own mature understanding at its own pace once seeded. The PCK must support the natural Pedagogic Flow to proceed with maximum degrees of freedom in deployment of learner's-and practitioner's intimate teaching and learning knowledge and instincts unfettered by rigid, reductionist, instructivist and standardised artefacts.

### 6.1.4 Pedagogical Relationship Types

Pedagogic relationships are not just associations between topics (or concepts or semiotic representations), they are rich in learning-oriented information. They may be purposeful, enabling the learner to better understand the reasons why topics have been inter-related by the tutor. At the enactment level they may also represent and link general and/or domain specific explanatory artefacts, e.g. coordinative presentation flow management or ICT-enabled augmentation artefacts such as gesture control in music teaching and learning, illustrations, counter-examples, worked examples, graphical representations, entertaining-engaging content e.g. metaphoric references, distractor tasks or tunes, caricatures, aphorisms, philosophical observations, light-hearted exaggeration, perceptive-cognitive (de)emphasis through selective audio-visual-tonal amplification, emotional (de)emphasis through jokes, story-telling, anecdotal references and linking to contrastive emotions e.g. to joy-grief, shock-horror-relief, serious gaming artefacts etc; in short anything that keeps the collaborative co-constructivist fires burning and thus the creative sparks of blended learning glowing.

In this section we have explored the issues relevant to the consideration of representation spaces for pedagogic information to best support dynamic responsive constructivist appropriation and adaptation of pedagogic delivery to facilitate blended but non-instructivist teaching and learning. We have introduced a PCK-empowered representation framework to include both the experiential and expert-based pedagogic delivery knowledge within a framework that lends itself to enhanced degrees of freedom for constructivist-constructionist blended teaching and learning and particularly serves the goals of easy maintainability as an open incrementally refine-able representational framework that can be evolved to reflect the mutual experiential development of both the teacher and the learner as they interact.

The framework developed within this section would enable the learner to investigate the teacher's pedagogical view of a particular topic as well as modelling how they themselves see the relationships between (sub)topics. This is in keeping with Davis and Linn (2003), [19], who pointed out that the quality of learning can be improved when students are aware of the level of their existing knowledge, and are able to control their learning process. This is to emancipate learners for evolving their own cognitive (meta)scaffolding towards more effective creative assimilation of new knowledge and skills.

This section concludes that e-learning development may be enhanced through the use of a meta-model which considers the inter-relationships between domain knowledge and what Shulman, [7], termed pedagogical content knowledge (PCK). Such a meta-model itself comprises a representational and Dynamic Pedagogic Flow (PFlow) Control Support Architecture within an overall Pedagogic Collaborative Working Environment reference architecture representation framework [20, 21] developed for the i-Maestro Project and founded on the development of a Topic Map-enabled mediating representation framework, as described above, to support Music Pedagogical Knowledge elicitation and PCK representation (MaestrOnto-SCR) together with formalisms to deliver fully Dynamic Contingent Pedagogic Material Generation and Flow Control support as needed per the requirements expressed by the user community including the Music Pedagogic Practitioners both within the i-Maestro Consortium [22] as well as the international group of Music Teachers and Learners who form the i-Maestro User Group.

## 6.2 Pedagogic Context Representation

In this section we first list a number of potential context descriptors that might be variably relevant to Pedagogic Delivery situations and as such might inspire the design of some context representation. Such taxonomies could also be helpful as a check list to serve as a reminder of such partitions in the domain that may be otherwise left unexplored during Pedagogic content and context knowledge elicitation.

However the world-views and data-views of individuals can be highly personal, dynamic and wide-ranging. It is appreciated that maintaining a context modelling exercise to cover all the dimensions that are explored in a systematic analysis, such as that given in the following section (6.2.1), could prove very difficult if not practically impossible to implement - for a number of user-related and computational reasons. Accordingly after considering the maintenance issues associated with the meta-model discussed in 6.2.1, the design approach taken in the definition of delivery context was to provide some definitive context triggers representation for flow control and leave the additional elaboration of contexts associated with particular Pedagogic Units to be user-defined through contextref : value pair placeholders in the PU meta-data since such PCK is deemed to be largely subjective and personalised in any case.

Some Pedagogic Context-related descriptors:

Pedagogic Delivery Spaces:

Beginner, Intermediate, Advanced (B,I,A):

- B/I/A Student Type
- B/I/A Instrument type
- B/I/A Instructor type
- ICT-savvy

- ICT-non-savvy
- ICT-phobic
- Experienced Instructor
- Early Instructor

Pedagogic Flow Types:

- Linear Lumped
- Linear Distributed
- Linear un-controlled
- Linear controlled
- Knowledge-Paced
- Assessment-Paced
- Linear Static
- Linear single-shot Dynamic
- Linear multi-shot Dynamic Contingent
- Uni-Linear, Multi-Linear, Systematic-Skip (hops),Open

Learning Stages:

- Earliest Learning
- Beginner
- Zero Musicality
- First basics lessons
- Intermediate Level Beginner
- Advance Beginner
- Advanced Adult
- Advanced Child
- Maestro
- Elementary School Teaching
- Secondary School Teaching
- University undergraduate level teaching
- Postgraduate (Maestro) teaching –most advanced level

Modalities:

- On/offline, Maestro online, Peers online
- Solo/group
- Ear Training, symbolic training, exercise session, composition,
- (Non) Augmented
- Private teaching face-to-face
- One-to-one
- One-to-two
- One –to-many
- Ear Training/singing
- Instrument Practice
- Voicing Practice
- Solo
- Harmony
- Orchestration
- Improvisation

### 6.2.1 An Activity-Centred Meta-model of Music Training

A metamodel for technology-enhanced music training being developed within i-Maestro aims at meeting the following aspects emphasised within the EC FP6 IST programme:

- It has to take into account the complexity of learning within complex and dynamic learning environments.
- It considers learning as a social process.
- It aims to support the systems blending old and new ways of learning.
- It is interested in how learning takes place in a technology-enhanced environment.

The specific objectives of the metamodel being developed within i-Maestro include:

- It aims at a unified educational model which in particular integrates music theory and practice training.
- In this, it intends to take into account key factors such as expressivity, creativity, interactivity, motivation and collaboration in cooperative learning settings.

It takes into account psychological, cognitive, social and cultural aspects of learning.

The metamodel for technology-enhanced music training is intended to be

- descriptive as opposed to prescriptive, i.e. it shall be able to represent observed constellations and processes relevant for music training,
- general, i.e. it shall not be able to cover different pedagogical approaches to music training and not be confined to predefined educational methods,
- expressive, i.e. it shall be able to capture the semantics and characteristics of pedagogical approaches.

The development of the metamodel follows an approach proposed as empirical theory approach by Balzer (1997) [23]:

- Definition of the target systems: The first step consists of determining the learning constellations and environments that the metamodel is intended to cover.
- Design of the model to describe the target systems: The metamodel is developed as a structure for describing the target systems.
- Collection of data guided by the model: Empirical data are collected and analysed in terms of the structures within the metamodel.
- Evaluation of the model against the data: The proposed metamodel is matched and possibly enhanced against the collected data.

The steps of model design, data collection and evaluation are iterated to make model and data converging.

### 6.2.2 Target Systems and Background of the Metamodel

#### 6.2.2.1 Target Systems

The metamodel is intended to integrate in a unified way the **major music training paradigms**:

- Music theory training: Symbolic or Theory Training comprises activities related to music theory, such as music editing, ear training, rhythm training, harmony training, composition, music history etc. (cf. DE2.1.1e).
- Music practice training: Practice Training describes activities related to instrumental playing and performance, such as play training, improvisation training etc. (cf. DE2.1.1e). The focus of i-Maestro is on music practice training related to string instruments.

These paradigms are realised within different **learning modalities**. i-Maestro takes into account:

- One-to-one teaching: One-to-one teaching refers to the face-to-face situation of one Teacher interacting with one Student.
- Classroom work: Classroom work is defined as activities involving the interaction between one or more Teachers and one or more Students (cf. DE2.1.1e). Typically, classroom works involve one Teacher with one or more Students.
- Distance learning: Distance Learning is a learning process which involves virtual communication between Teacher and Student across geographically separated location and mediated by some communication link (cf. DE2.1.1e).
- Self-study: Self-study is a study setting which is not instructor-led and may involve one or more Students studying under their own initiative (cf. DE2.1.1e). For example, the daily study at home.
- Cooperative work: In a collaborative or cooperative setting two or more Students are working together (cf. DE2.1.1e).

#### 6.2.2.2 Music Education and Instruction Theory

Music education and instruction theory (e.g. Mahlert 1997), [24], is concerned, among others, with the following aspects and elements of music learning:

- Learning objectives: Desired learning outcomes refer to knowledge, qualifications and skills related to music. Verbs occurring repeatedly in the description of learning objectives include knowing, understanding, applying knowledge to solve problems, expressing one's opinion or – particularly in the music area – showing artistic expressivity.
- Learning contents: Music training curricula so far most often focus on learning contents rather than learning outcomes. i-Maestro is interested in contents of music theory training as well as music practice training.
- Learning and teaching activities: Among the approaches to the analysis of activities within music training situations some have lead to taxonomies of activities characteristic for the roles of the teacher with respect to the students, which include activities as asking, presenting, explaining, observing or assessing on the teacher's side and asking, answering, imitating or discovering on the students' side (e.g. A. Ernst 1991. Lehren und Lernen im Instrumentalunterricht. Mainz, as reported in Mahlert 1997:1514 [24]).
- Learning and teaching methods: Learning and teaching activities are embedded in learning and teaching styles, forms and methods. In these, activities are considered as targeted towards learning objectives and are combined within a structured delivery of activities and resources.
- Learning and teaching means: Learning and teaching activities make use of learning means, like material and tools.
- Institutional, social and cultural environment: Music education theory also addresses aspects like whether music training takes place in general education institutions, music schools, conservatories, higher education or adult education. Special considerations are dedicated to ways of integrating the student's every-day world and experiences into music training situations.

A descriptive, general and expressive metamodel of music training must be able to cover these aspects.

#### 6.2.2.3 Educational Modelling

The scope of the metamodel to be proposed in this document is similar to that of the pedagogical metamodel behind EML (Koper 2001), [25]. The metamodel integrates the pedagogical considerations feeding into the i-Maestro software and tools.

The metamodel behind EML comprises four main components:

- Theories of learning and instruction: The EML metamodel is a meta-model to pedagogical models of learning and instruction, like behavioristic, constructivist or situationalist instruction.

- Learning model: The learning model describes how learners learn in a ways abstracted from the theories of learning and instruction. It takes into account the learner, learning activities, learning situations and learning communities.
- Unit of study model: The unit of study model gives a structure for units applicable in a technology-enhanced environment integrating components from the learning model and relating it to material, resources, tools and services for learning.
- Domain model: Learning is related to a domain which for i-Maestro is music. The domain model is not specified further in the EML metamodel which is not confined to certain areas of learning.

The metamodel described in the following paragraphs is influenced by the conceptual vocabulary of the IMS Learning Design in particular by the concepts of (the citations are taken from the IMS LD Information Model, see also Koper & Olivier (2004) [26]:

- Learning objectives: "The learning objectives are the overall learning objectives to be attained by learners who complete the unit of learning. Learning objectives can be specified on several levels of detail. In IMS Learning Design, designers can choose to specify learning objectives at two levels, each with advantages and disadvantages. First, it is possible to define the learning objectives at the global level of the unit of learning. Second, it is possible to specify learning objectives for every single activity in the learning design."
- Prerequisites: "The prerequisites specify the overall entry requirements for learners for doing the unit of learning. As with learning objectives, the prerequisites can be provided at the level of the unit of learning and/or for individual learning activities."
- Roles: "Roles allow the type of participant in a unit of learning to be specified. There are two basic Role types: Learner and Staff. These however can be sub-typed to allow learners to play different roles in certain types of learning activity such as task-based, role-play and simulations. Similarly support staff can be sub-typed and given more specialized roles, such as Tutor, Teaching Assistant, Mentor, etc. Roles thus lay the basis for multi-user models of learning."
- Properties: "Properties are an essential part of monitoring, personalization, assessment and for user-interaction."
- Activities: "Activities are one of the core structural elements of the 'learning workflow' model for learning design. They form the link between the roles and the learning objects and services in the learning environment. They describe the activities a role has to undertake within a specified environment composed of learning objects and services."
- Activity structures: "Activities can be aggregated into an activity-structure which provides the mechanisms to structure activities and referenced units of learning into a sequence or a user-selection."
- Environment: "Activities take place in a so-called 'environment', which is a structured collection of learning objects, services, and sub-environments. Learning objects are defined here, as any reproducible and addressable digital or non-digital resource used to perform learning activities or support activities. Besides resources which can be defined at design time, there are numerous so-called 'service facilities' used during the teaching and learning, for instance, a discussion forum or some other communication facility."

#### 6.2.2.4 Social, Psychological and Cognitive Aspects

In addition, the activity-centred metamodel builds on ideas from the theory of social schemata proposed by Balzer (1993) [27]. The social schemata are attractive to the development of the metamodel for several reasons:

- Balzer aims at a general and precise theory of social institutions and practices. His theory is formalised in a way that makes the theory implementable technically in e.g. a knowledge-based system.
- Social schemata take into account action types and concrete actions. This is near to the objective of developing an activity-centred metamodel for music training.

- Balzer is concerned with actions affecting other actors. This opens ways to describe interactions between actors.
- Social schemata consider intentions and beliefs and integrate internal models of actors. This enables to integrate psychological aspects.

Social schemata are structured into two main building blocks:

- The macromodel analyzes social institutions and practices on the level of social groups and their characteristic action types. The analysis of relations between groups focuses on the so-called status relation influences how a representative of one group can or does affect the actions of the representatives of another group. The internal model of a group comprises the concepts and beliefs common to the members of the group as far as they are relevant to their social context.
- The micromodel analyzes social institutions and practices on the level of individual actors and the actions performed by these actors at certain locations and at certain points of time. Individuals can be assigned to groups and their actions are of an action type defined on the level of the macromodel. Individual's internal models included in the micromodel to account for their individual intentions, believes and decisions. Individuals are embedded in a social network.

However, we do not directly adopt Balzer's theory to define our metamodel.

There are further concepts of social and psychological theories of action with respect to activity (e.g. O'Neil 1995 [28], Csikszentmihalyi 1999 [29], Boudon 2001 [30], Eckensberger 2001 [31], Hacker 2001 [32], von Cranach & Tschan 2001 [33]) which are relevant to the proposed metamodel.

- Action types: Different categorisations of action types have been proposed, among them e.g. the distinction between goal-oriented vs. process- or experienced actions. This seems to be particularly expressive in the area of music. Another taxonomy which appears to be relevant in the context of music learning – in particular within collaborative settings – distinguishes instrumental, communicative and strategic actions.
- Action planning: Actions are organised sequentially as well as hierarchically. Goal-oriented actions can be considered as a sequence of goal selection – orientation – planning – execution – evaluation. Regarding the hierarchical organisation there are, besides subgoals to goals, different levels of regulation like the motor, perceptual and cognitive level.
- Motivation and rationality: In the context of motivational aspects in music learning a useful distinction is the one between instrumental rationality, which is directed towards purposes or objectives, and axiological rationality, according to which goals or actions might be selected because they correspond to certain values.

### 6.2.3 Developing an Activity-Centred Metamodel of Music Training

#### 6.2.3.1 Basic Terminology

The following exposition of the metamodel adopts as crucial terms among others:

- Activity: "Activities are motivated and regulated by higher-order goals and are realized through actions […]." (Hacker 2001) [32]
- Actions: "The concept of action refers to the intended behaviour of an agent." (Cranach & Tschan 2001), [33].
- Actor: "an individual interacting with other persons or with objects as a thinking organism, as opposed to interacting as a purely physical being" (O'Neil 1995) [28].

The important aspects here are the relation between higher-order activities and their being realised by concrete actions which are also intended actions and situatedness of an actor within his environment including his interaction with other actors and with objects.

#### 6.2.3.2 An Activity-Centred Metamodel for Technology-Enhanced Music Training

The metamodel will be introduced in several steps.

#### 6.2.3.3 Describing Learning Modalities

The learning modalities to be covered by the metamodel (see above) differ from each other in terms of e.g. the number of actors and their roles, the spatial relation of actors – e.g. one-to-one teaching vs. distance learning – and the communication means necessary due to these spatial constellation. To describe the learning modalities the following metamodel items are proposed:

- R: set of roles $\{r_1, \dots, r_m\}$
- A: set of activities $\{a_1, \dots, a_n\}$
- O: set of objects $\{o_1, \dots, o_l\}$
- M: set of communication means $\{m_1, \dots, m_f\}$
- ch: characteristic function $R \rightarrow A^k$ $(k \leq n)$
- d: distance function $R^2 \rightarrow [0,1]$

Learning modalities could therefore characterised by using the structure ‹R, A, O, M, ch, d›.

#### 6.2.3.4 Describing Learning Scenarios

Learning modalities give a global and static picture of the learning situations. Concrete action sequences within these modalities constitute different learning scenarios. To describe these we propose the elements:

- I: set of individual actors $\{i_1, \dots, i_m\}$
- C: set of actions $\{c_1, \dots, c_n\}$
- realize: temporal function $(I, t) \rightarrow C^k$ $(k \leq n)$

These are related to the above specified structure ‹R, A, O, M, ch, d› by:

- role: temporal function $(I, t) \rightarrow R$
- type: action type function $C \rightarrow A$
- use: $C \rightarrow O^q, M^r$

The structure proposed to capture learning modalities is therefore complemented by ‹I, C, T, realize, role, type, use›.

#### 6.2.3.5 Domain Model

Learning is related to a certain domain. For this metamodel it is the domain of music theory and practice. The domain model defines the relevant concepts and skills as well as their mutual relations. In the context of the metamodel there is no elaboration of the domain. However, the domain is crucial in defining learning and teaching actions. Thus, the metamodel includes an item D for the domain.

#### 6.2.3.6 Learning and Teaching Actions

Actions are learning actions if they are targeted at one or more learning objectives. In addition, learning actions may have entry requirements, i.e. prerequisites must be accounted for.

- L: set of learning objectives $\{l_1, \ldots, l_x\}$
  - related to the Domain
  - shaped by the regulative framework (e.g. curricula)
- P: set of prerequisites $\{p_1, \ldots, p_y\}$
  - related to the Domain and regulative framework
- def: learning action definition $C \to L^q, P^r$

Additional elements in the metamodel are therefore included as ‹C, L, P, def›.

#### 6.2.3.7 Actors' Internal Models

To be able to describe e.g. the planning of a sequence of learning actions to reach at a given learning objective related to the learning domain – including aspects of motivation –, we integrate into our metamodel a representation of an assumed internal model of an actor. While Balzer defines internal model at the level of groups as well as of individuals we confine the notion of internal model to the individual learners and do not define internal models of roles.

- L*: representation of learning goals $\{l^*_1, \ldots, l^*_u\}$
- S*: representation of learning status
- W*: representation of environment $\{o^*_1,\ldots,c^*_1,\ldots, i^*_1,\ldots\}$
- D*: representation of domain concepts and skills
- V*: representation of personal values
- C*: action plan $(c^*_1, \ldots, c^*_z)$
- repr: internal model relation $I \to N$

A last structure to be integrated into the metamodel thus consists of ‹L*, S*, W*, D*, V*, C*, repr›.

#### 6.2.3.8 Summary of the Metamodel

The graphic gives a summary of the metamodel. Details of the links from the internal model to elements within the learning environment and process are omitted in the graphic.

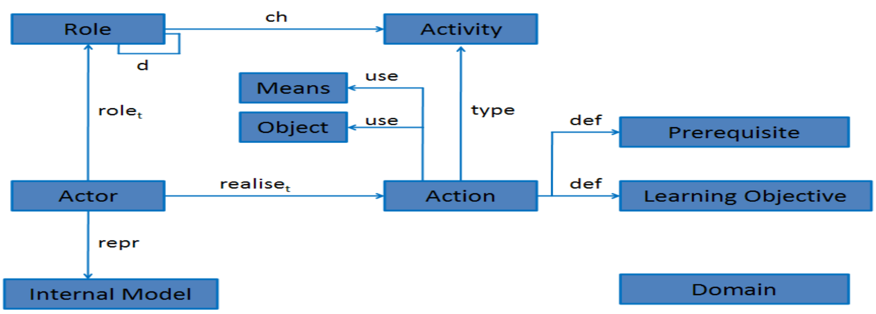

Figure 22: Activity-centred meta-model

### 6.2.4 Conclusions

Evaluating the proposed metamodel against the objectives formulated above leads to the following observations:

- The metamodel is descriptive; it does not prescribe the Teacher or Student how to act in the context of technology-enhanced music training.
- The metamodel is general. It is not biased towards any specific pedagogical approach.
- The metamodel is expressive. When described by the metamodel learning modalities will differ e.g. in R, d or M. Learning scenarios will differ e.g. in I, C, realize, role. Different pedagogical approaches will differ in e.g. A, C, O.
- The metamodel takes into account psychological and cognitive aspects. E.g. it can cover different forms of learning like concept or skill learning by relating the learning objectives to the domain model. Motivational factors like instrumental and axiological rationality can be accounted for as the internal model includes a representation of objectives as well as of values.
- However the implementation and maintenance challenges of a context modelling exercise to cover all

The dimensions set out above will have to wait to be explored after the current design as referred to under section 6.2. and described in the following sections is implemented and refined.

# 7. Formalisation of I-MAESTRO Music Training Paradigms

## 7.1 Sequencing of I-MAESTRO Music Training Units

IMS Simple Sequencing (IMS SS) is the first step towards a definition of sequencing in e-learning. "IMS SS declares the relative order in which electronic learning activities are to be presented to a learner and the conditions under which a resource is selected, delivered, or skipped during presentation"[2].

Simple means, the number of strategies is limited. They are very common and should fit every possible subject. This means, in an integrative and complex subject like music, additional rules have to be defined. It is not simple, it is just common. IMS SS relies on the concept of learning activities, such as content or test questions. Activities are associated with other activities into a hierarchy, resulting in an activity tree. A parent activity and its children are referred to as a cluster of activities.

An activity has one or more objectives associated with it. Objectives are typically used to record the scores of test items. Objectives may also add objective maps, so that the result of an assessment item may be used to influence the sequencing behaviour in a widely separated branch of the activity tree.

An activity may additionally include auxiliary resources. Auxiliary resources provide the learner with help, glossaries or other context sensitive services. Activity clusters have sequencing rules and limit conditions associated with them. Sequencing rules are used to influence the order of activities presented to the learner. Limit conditions, such as attempt limits, duration limits and date limits, are used by the sequencing rules to further influence when an activity is sequenced next to a learner.

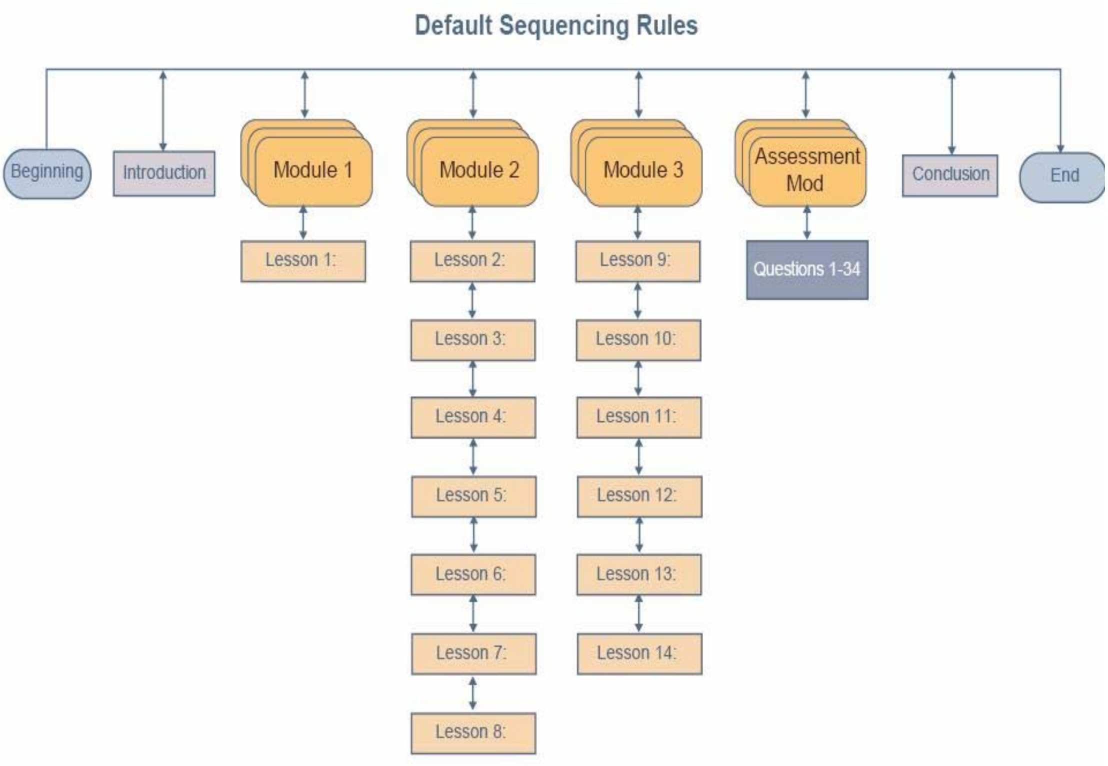


Figure 23: default sequencing flow control of pedagogic activity structures

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[2] http://www.icodeon.com/pdf/ss2brief.pdf Warwick Baily, 04-09-2005 CETIS, University of Bolton

The learner is presented with content first the introduction, then each module and lesson in a pre-determined order including the conclusion.
The learner will complete the content by taking the assessment.

All learning activities have the following characteristics:
• Learning activities have a discrete start and finish
• Learning activities have well-defined completion and mastery conditions
• Learning activities can consist of sub-activities, nested to any depth
• (Attempts on) Learning activities occur in context of (attempts on) their parent activity, if one exists

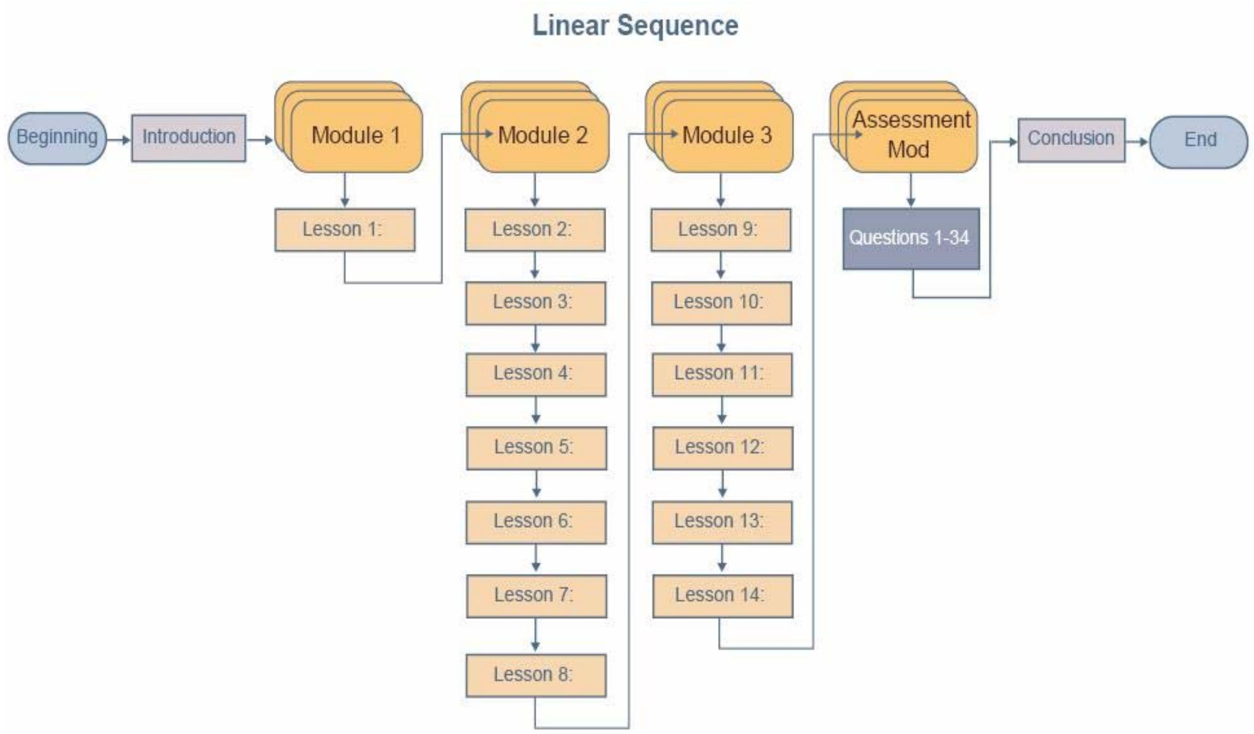



Figure 24: Linear flow sequencing of pedagogic activity structures

The learner is presented with content first the introduction the each module and lesson in a pre- determined order including the conclusion.

The learner will complete the content by taking the assessment.

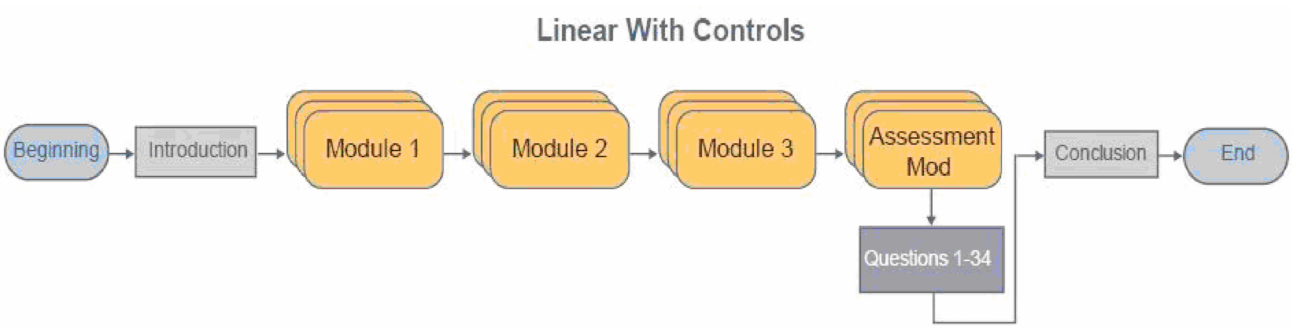



Figure 25: Pedagogic activity flow with linear controls

The learner is presented with and most progress through the content in a pre-determined order, first the introduction then each module and lessons in order.
Linear with User Interface Control varies from Linear by the ability to change the look and feel of the screen the LMS look and feel.

The learner will complete the content by taking the assessment.

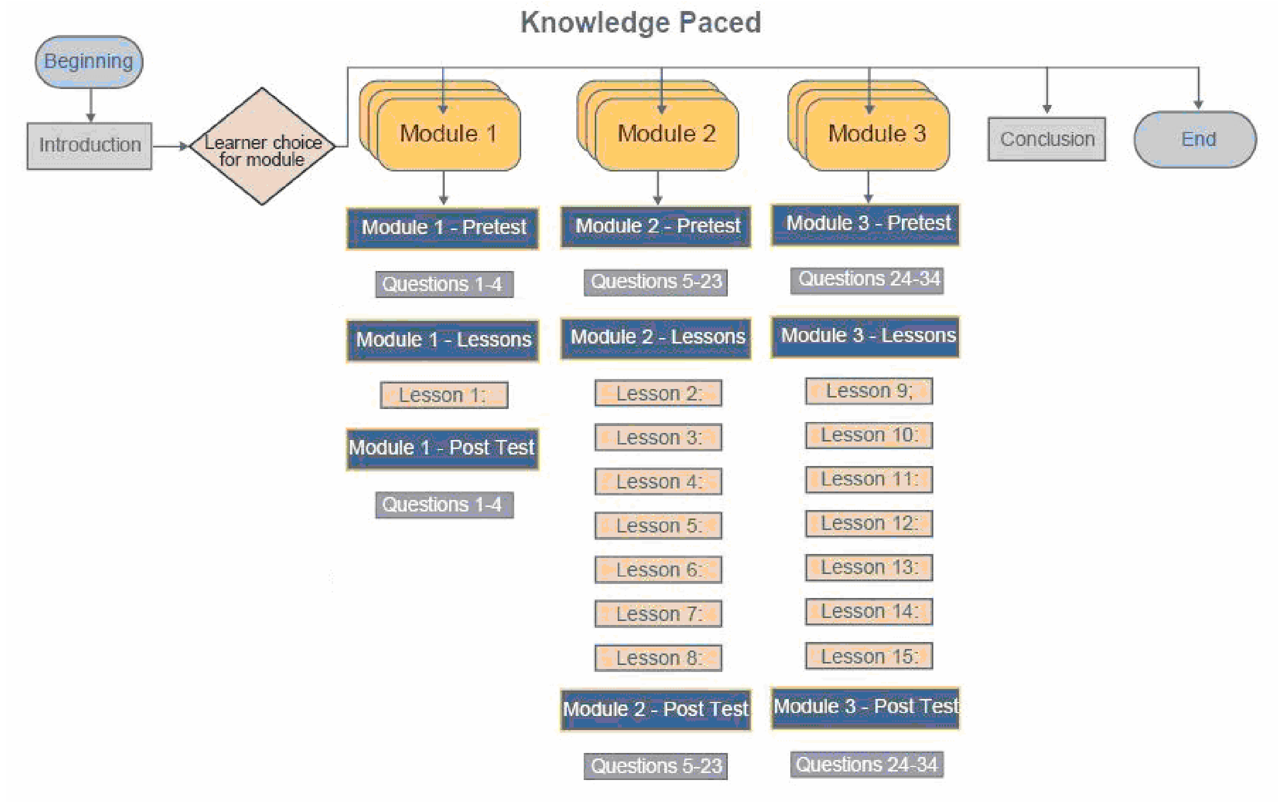



Figure 26: knowledge-paced pedagogic activity flow control

**Knowledge Paced Flow Control:**

The Learner must complete the introduction and then may proceed to the pre- test of the first module pre-test questions are directly related to the objectives for the content or lessons. When the learner takes a pre-test, the learner, must attempt each question in order. While in a test learner cannot choose to exit the module exam before completing it.

For each module, if the learner obtains a passing score on the pre-test module's learning objective has been satisfied. The learner tests out of the content and post-test.
If the learner does not obtain a passing score, they will then proceed to the content and post-test.
Upon completion of the content learner will proceed to the next pre-test, repeating the previous steps until all of the content is completed.

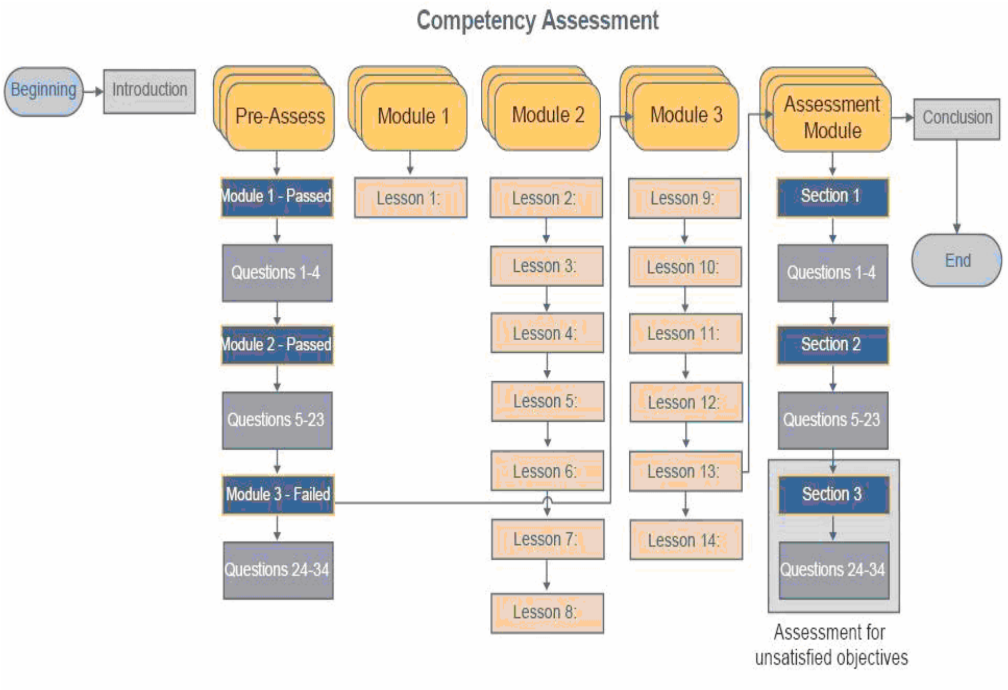



Figure 27: competency-assessment-based pedagogic activity flow control

**Competency Assessment Based Flow Control:**

This learning strategy is a variation of Knowledge Paced, but the pre-test assessment module is on the total amount of content rather than module by module. The learner is first presented with the introduction and then proceeds to the pre-test for all the content modules.

The learner is then presented with a pre-test assessment module that evaluates the learner's mastery of each of the module objectives. If the learner satisfies the objective, they have tested out of the content that relates to the objectives and test questions.

If the learner does not satisfy the objective, they are presented with the content related to unsatisfied objectives. After the learner has completed all of the required content, if any, an exam is presented that re-tests the objectives not satisfied.

The following Sequencing possibilities are useful variations to increase the "joy and efficiency" of e-learning.

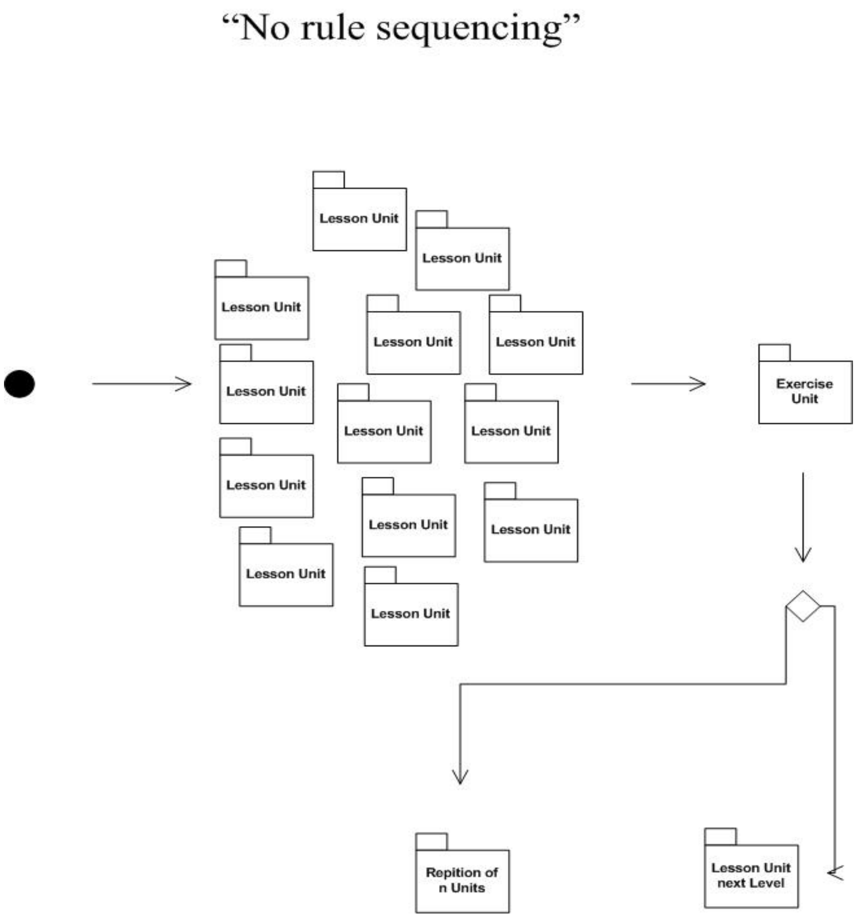



Figure 28: Non-rule-based sequencing of pedagogic activity structures

"**No rule sequencing":**

"No rule sequencing" provides a possibility to let the student learn- to- learn. There are no strict sequencing rules, just start point, a certain amount of Lesson with variations regarding type, interactivity and exercise Units and a final test. How the student manages a Lesson, is his own decision.

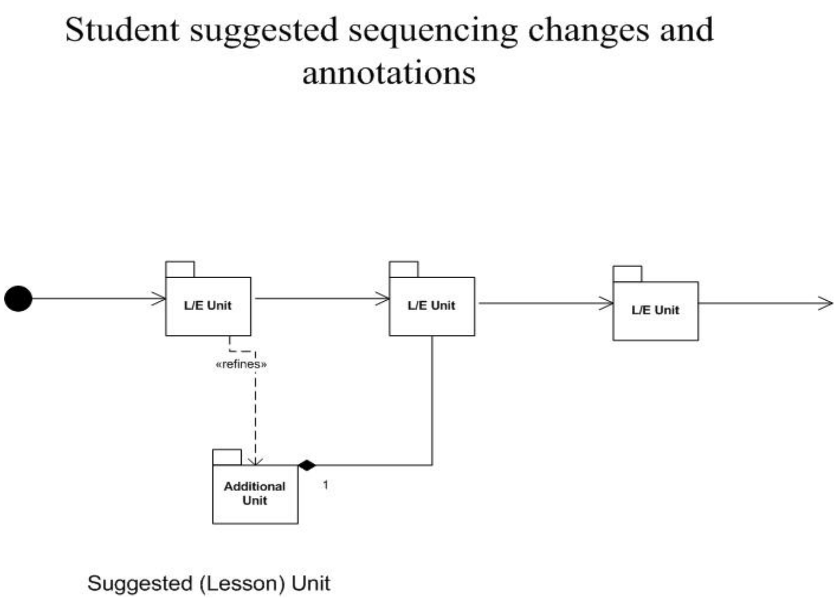



Figure 29: Student-led pedagogic flow modifications

In this example students have the possibility to make their own annotations and can suggest different units. They can change sequencing from a student's point of view. This could be useful for other students, e. g. getting stuck in the same theoretical problem and not understanding the following units any more.

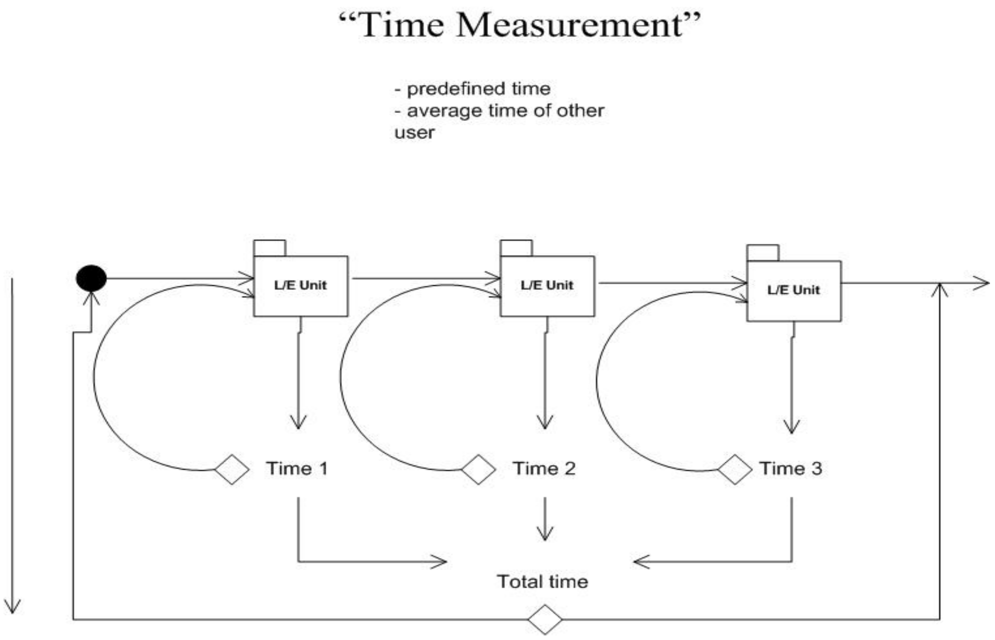



Figure 30: Timed learning based pedagogic flow control

## 7.2 Music Training Activities and Activity Structures

Essentially we conclude that the Music Pedagogic Activity Structures should be based on the following criteria:

- meet the requirement above in the EML section "that the current learning object centric view of the e-learning world should evolve to a learning activity centric view"
- pick up the Actors category in ALBENIZ's Exercise Template proposal
- pick up the play metaphor put forward in IMS
- meet pedagogical paradigms and settings like e.g. problem based learning
- enable the representation of lesson plans as collected at http://www.eduref.org/cgi-bin/lessons.cgi/Arts/Music
- probably allow for more innovative as well as explorative and creative music learning approaches

# 8. I-MAESTRO Training Specification Language (TSL)

## 8.1 PCK-empowered MaestrOnto-SCR: the I-Maestro PM Generation & PFlow Control Support TSL Framework

In this section we briefly highlight the salient features of those theories of teaching and learning which have formed significant landmarks in our understanding of the interplay of such intricate influences as are instrumental in the essential chemistry of teaching and learning experiences. From a standpoint that privileges the role of Pedagogical Content Knowledge (PCK) in pedagogic delivery, we draw on important insights from researchers and philosophers relating to the socio-cognitive dynamics of teaching and learning, e.g. the constructivist-constructionist and Voygotskian influences, as well as the expressed needs of Music Pedagogy Practitioners, to devise a framework for Training Specification Language (TSL) and Pedagogic Flow (PFlow) Support to facilitate blended learning in music education. This framework which includes a mediating representation (MaestrOnto-SCR), a Pedagaogic Unit Schema, and, a dynamic contingent PFlow control interpreter, (PFlow Support), is to accommodate the essential features for the i-Maestro technology-enhanced music Learning Unit enactment. This is conformant with the underlying psycho-social, cognitive and semiotic phenomena that influence the continuously evolving and maturing lifecycle processes of pedagogic experience. It can be exploited to support PFlow control based on the delivery context and the needs of the practitioner’s pedagogic moment, as viewed by the participants, to orchestrate a mutually responsive and informing experience including dynamically invoked assessments and multiple problem-based constructivist-constructionist flaw-fixing trajectories in teaching and learning. Such trajectories can be sequential uni-linear, overlapped or run in parallel. Thus we conclude that the MaestrOnto-SCR framework, contextualised within a reference architecture for collaborative teaching and learning communities, can facilitate the representation of music PCK and offer the learner and teacher the opportunity to usefully experiment with new ICT-augmented modalities for blended learning.

As discussed earlier in this document (section 6), the widely know view is that Research for a framework for mediating representations is relevant and essential to eliciting Pedagogical Content Knowledge (PCK) as well as using and updating such elicited PCK to allow Pedagogic Material Generation and Flow Control support in technology-enhanced blended learning. In this section we first review some of the pedagogic influences that motivate collaborative constructive learning followed by a broad outline of the main layers of a reference architecture as may be required by collaborative learning communities. This is followed by an overview of a Topic-Map-enabled mediating representation to support PCK enactment, applied to the music pedagogy domain (MaestrOnto-SCR) followed by briefly highlighting some of the key features of the Training Specification Language (TSL) and the Pedagogic Unit (PU) Schema to be deployed for Pedagogic Material Generation and Flow control support based on the PCK-empowered representation of MaestrOnto-SCR.

### 8.1.1 Key Learning Theoretic Motivations

In this section we have briefly highlighted the key learning theoretic influences which have motivated our research towards architectures to support collaborative blended teaching and learning. We have given an outline description of the possible layers of a reference architecture to support a collaborative communities learning environment. We have outlined a representation for Pedagogic Content Knowledge (PCK) referred to as MaestrOnto-SCR to underpin the pedagogic unit representation and the pedagogic flow (PFlow) control support. Further we have outlined the key features of such PCK-empowered representation in terms of the Topic-Map-enabled MaestrOnto-SCR and associated pedagogic units (PU) Schema and Training Specification Language (TSL) control structures to support the dynamic creation of pedagogic unit partial plans and sequences and thereby responsive PFlow control support at execution-time to achieve dynamic pedagogic goals.

#### 8.1.1.1 Cognitivist Influences

Cognivitism is concerned with the underlying cognitive processes motivating exploration, organising and synthesising of learning content. Here the instructor is seen as managing problem-solving and structured search activities, particularly in the context of group learning strategies.

Learners are supported in processing, storing, and retrieving information for use. (Bruner's Discovery Learning), [34]. Vygotsky's Zone of Proximal Development (ZPD) focuses on interactive problem solving [35]. This privileges the social dimensions of learning and views learners and teachers as partners engaged in mutually supportive or co-generative enquiry and discovery, each customising their own learning and benefiting from the opportunities for exchanges of insights in social interaction to follow their own developmental journey on individual trajectories of learning and personal growth (Zones of Proximal Development).

#### 8.1.1.2 Constructivist Influences

These seek to promote the continuity of building on known concepts. Piaget referred to 'Constructivism' in relation to this style of learning [36]. He suggested that, individuals accumulate new knowledge from their experiences through processes of *accommodation* and *assimilation*. Constructivism encourages learners to create their own unique education because learning is based on prior knowledge.

Learning is seen as interactive, dialogic and based on prior knowledge such that learning is designed to assist students to build on what they know. Teachers are not the sole possessors of knowledge and perspective but co-learners and guides. This is associated also with important learning perspectives such as inquiry-based learning which is deemed more prevalent in adult learners (Knowles' Andragogy) [37].

#### 8.1.1.3 Collaborative Learning Communities (CLC) Influences

Working in groups brings some characteristics such as synergy, the ability to consider more information, cognitive stimulation and member learning from other members, which can be very useful in improving the learning process [38], Kedong (2001), [39], describes collaborative learning as "…a process that encourages constructive discussion of ideas, collaborative arguments, and interactions among participants…" It has been proved that children who work in groups are more successful than those who work alone.

#### 8.1.1.4 Engineering for Blended Learning to Support CLCs

Learning design for blended learning should aim to support the integration of re-usable, shareable components needed to create a learning process that meets individual learning goals, emancipates learners and teachers from some of the spatio-temporal and resource constraints of fixed learning structures and supports variation-theoretic approaches which accommodate both learning autonomy and social learning and privilege a constructivist-contructionist approach rather than a monolithic instructivist regime.

Thus learning design has to promote more effective learning support by carefully modelling the practitioners' Pedagogical Content Knowledge (PCK) plus an adaptive representation and interpretation of the Pedagogic Flow Control so as to provide a PFlow support framework for technology-enhanced blended learning. IMS-LD represents an earlier attempt towards providing a generic and flexible language to describe a wide range of learning activities in e-learning. This was based on the Educational Modelling Language (EML) [40]. EML describes how teaching and learning is conducted based on the available resources. Another development in this area is the Learning Activity Management System (LAMS) [41] which has built on IMS-LD. This offers support for creating sequences as well as an effective user interface for pedagogic workflow design [42]. The IEEE Learning Technology Standards Committee and the IMS

Global Learning Consortium have proposed some high level standards for describing reusable learning objects.

Currently the dominant and widely implemented standard in this context is the SCORM Content Aggregation Model [43]. However the problem is that SCORM shareable objects, like any fixed templates, used without a PCK-empowered mediating representation to customise them for situated teaching and learning, will amount to imposing a regime with fundamentally instructivist assumptions as the price to be paid for shareability. The widely shared views of experienced teachers tend to support the collaborative co-constructivist approaches whereby teachers and learners *negotiate and customise* their *pedagogic journey*, *co-generative enquiy* and knowledge construction rather than having fixed structures imposed upon them.

In our work we privilege a PCK-empowered [44] mediating representation which can use shareable learning objects to create PCKs which are thus augmented and customised to deliver situated teaching and learning. This benefits from the teacher's and learner's insights about how best to pursue mutually supportive constructivist and flexible pathways toward personalised learning objectives i.e. (meta)scaffolding their learning, within an environment supported by a technology-enhanced architecture for blended and collaborative learning. Thus our architectural approach represents a move away from naive advocacies of technology towards supporting learner-centric constructivist-constructionist collaborative creativity in pedagogy. This can in turn confer multiplier benefits once an integrated ICT-enabled and PCK-empowered infrastructure is in place to act as the backbone system to motivate and support networks of collaborative learning communities.

#### 8.1.1.5 Cooperativity Spaces Support for Negotiating My/Our PCKs

In attempting to formulate an augmentive reference architecture to support blended teaching and learning we would need to recognise that such a reference architecture would necessarily have to be a type of collaborative working environment or social computing space support architecture and one could reasonably propose to characterise it in terms of five reference architectural layers which can be listed as follows:

i. **Upperware Reference Architecture** (including active cooperativity support e.g. systems for: Pedagogic Goals (P-Goals) setting, Pedagogic Flow (PFlow) control, mutual process awareness/transparency support, mixed modalities support e.g. virtual/physical/synchronous/asynchronous/co-located/distributed modes, PCK authoring and re-composition management, tools re-configuration, context dimensioning /switching and virtualisation layer and models management, cooperativity flaw-fixing/ trouble-shooting support to ensure optimisation, situated self-adaptation and dynamic responsive match-making to learners'-teachers' requirements, pedagogic spaces selection, alerts reporting and syndication.

ii. **Learner/teacher-Intimate Interfaces** (Dynamic Personalisation) Reference Architecture layer
iii. **Building Block Components Reference Architecture** (UML, OWL, service descriptions).
iv. **Software Integration Reference Architecture** (APIs, middleware, access support to synchronous, asynchronous social spaces e.g. collaborative pedagogic content negotiation, creativity tools support, Wikis, Blogs, MSN chat, conferencing, Skype etc).

v. **Context-sensing and security to support Constructive Engagement** (Topic Map–enabled support for context persistence and tractability, context sensing, trust domain modelling, mutual peripheral awareness (opportunist learning support), multi-data, multi-view perspectives modelling, ethno-cultural /discipline-specific pedagogic cooperativity, SLAs, networked cooperativity etiquette modelling, ID management).

A schematic of the reference architecture of the main layers of a collaborative learning environment appears in figure below.

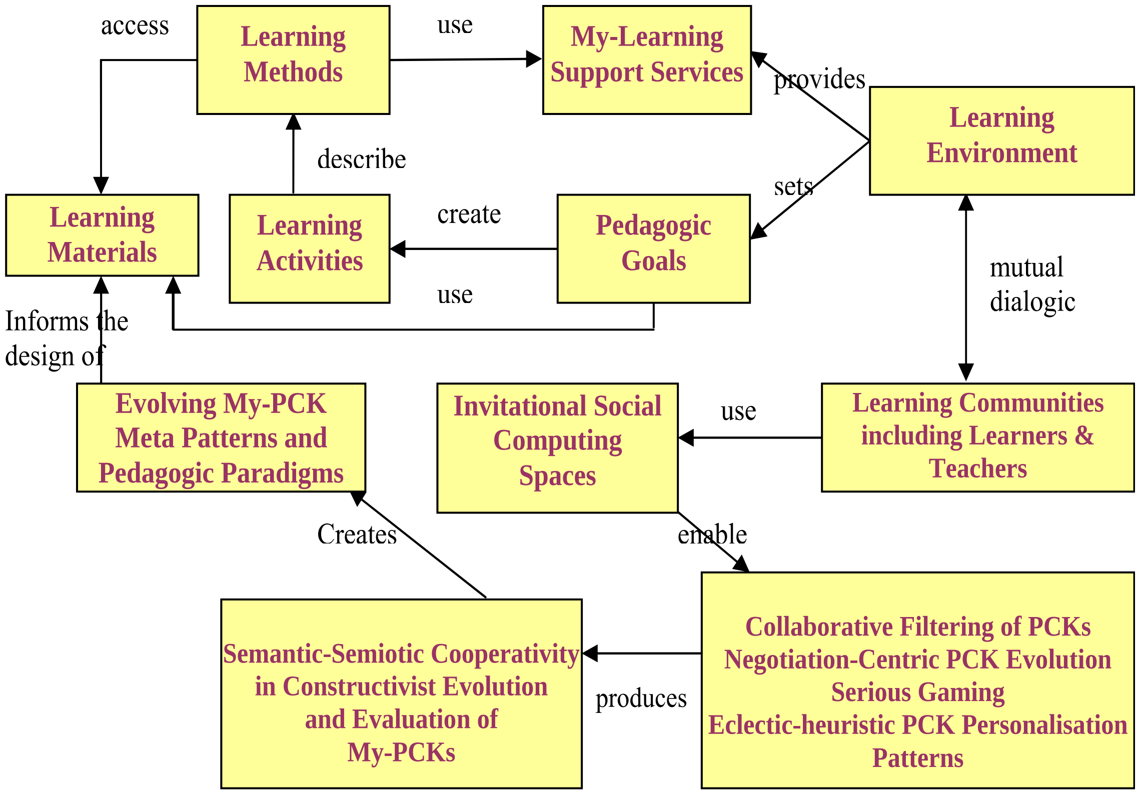



Figure 31: A schematic reference architecture of the main layers of a collaborative learning environment.

### 8.1.2 Semantic-Cooperatively Revisable Learning Unit Ontological Networks: MaestrOnto-SCR

MaestrOnto-SCR, is a mediating representation exploiting the XML-based standard known as Topic Map to support the TSL-deployable implementation of blended learning with PM generation and Pedagogic Flow (PFlow) control support. This can offer multi-model, multi-view mobilisation and revision of pedagogic knowledge for any discipline but particularly for music teaching and learning with its highly dynamic variation-theoretic requirements. This is in order to provide a highly personalise-able (context-aware) map of user-intimate pedagogical relationships which accommodate the dynamic multi-view associations amongst the domain knowledge elements, the pedagogic knowledge elements, and, the personal experiential knowledge of the pedagogic practitioner i.e. the Pedagogical Content Knowledge (PCK) from different actors' (e.g. teacher's-learner's) viewpoint at any time. In essence this includes an experienced teacher's knowledge of how to provide dynamically responsive and personalised pedagogic delivery in particular situated contexts.

As such MaestroOnto-SCR can represent the relationship of learning units at any level of abstraction to represent the dynamic *patterns-of-relating* of any domain object or concept to any other. This amounts to a capability for representing the current mindset of any actor about how any atoms or meta-units of anything are dynamically related from any viewpoint e.g. how individual musical notes are related to each other or to any piece of music say from the point of view of a composer, teacher, student, or any performer, or, how various genres of music or works of the same or other composers or music teaching methods are related from any arbitrary idiosyncratic viewpoint.

Thus MaestrOnto fits well with the criteria for dynamic emergent representation of music learning units as an open standard which will naturally integrate with the emerging Symbolic Music Representation (SMR) i.e. will be also SMR-compliant [45]. Further, MaestrOnto-SCR can be integrated with Bayesian Belief Networks (BBN) to allow a probabilistic or fuzzy map of the learning units to be deployable as a highly context-dependent map of music learning units relationships and thus confer the highest capability for contingent flow control support in blended delivery of learning units with TSL support.

The problem-based teaching mindset is particularly relevant to typical music pedagogy practice whereby we can regard a learning unit as a remedial object in the sense of e.g. a performance flaw-fixer that is administered (deployed) by the teacher dynamically as and when appropriate. At any time there may be multiple flaws in a student's understanding or performance as discerned by the teacher who would invoke the appropriate strategy to fix flaws at the right time through selected means – exploiting his experience i.e. his PCK. In this way the MaestrOnto-SCR allows the dynamic revision and mobilisation of pedagogic knowledge of various teachers or students about what remedial step best works for them as a cure for a particular music learning or teaching difficulty.

Figure below serves as a schematic of just one of the instances of a MaestrOnto map. Please note that the symmetry or sequentiality in the labelling of nodes in this figure is purely to facilitate the illustration of a first tentative pedagogic map and is not a requirement for the emergent and transient map which can dynamically reflect any of the many (n-to-n) associations of pedagogic units in any idiosyncratic order to represent the instantaneous and evolving role of pedagogic units in an unfolding teaching-learning situation. This is to be viewed subjectively as one of the many personal data-views of an observer at some time during a pedagogic or reflective-creative moment. The nodes can link anything from notes to symphonies or teaching methods or student levels [e.g. Beginner (B), Intermediate (I), Advanced (A)]. In this figure the particulars of each topic can be defined in terms of their properties and the semantics of their relationships can be further elaborated in terms of their associations and their occurrence roles. Also this part of the map can be associated with other topics for derived information (e.g. signs representing any orchestration of learning units at any level such as music notes, bars, etc). Therefore here we have given an example of one of the many ways whereby the Topic Map constructs can be deployed in MaestrOnto-SCR to allow a gracefully integrative dynamic Ontological Networks-based and TSL-controlled support for technology-enhanced delivery of blended music teaching and learning.

#### 8.1.2.1 Mapping from Topic Map Constructs to MaestrOnto-SCR

The ISO/IEC 13250 defines a Topic Map as an SGML or XML document (or set of documents) in which different base set of architectural forms, are used to represent topics, occurrences of topics, and relationships (or "associations") between topics. The Mapping between the key concepts of Topic Maps and some of the music pedagogy constructs can be briefly highlighted as follows:

**Topic:** A topic, in its most generic sense, can be any "thing" e.g. a learning or pedagogic unit or any aspect thereof with appropriate metadata.
As a general rule of thumb, the topics should be anything that may require re-visiting and possible modification. Appropriate metadata should be already available for the topics. Normally, such metadata will be descriptive or content-metadata (e.g. SMR) and its details will vary according to the type of topic. Here the topics can be considered as the learning units, or any aspect of any learning unit, its associations with any other thing or unit, its occurrences, roles, etc.

**Topic Type:** This allows for topics to be classified in some order and/or identified as a (sub)group.
This will allow each of the Topic types to be represented using the same meta-data. In MaestrOnto-SCR this can be for example music type, note type, learning unit or exercise unit type etc

**Topic Occurrence:** The topics as defined are thereby accorded some existential context characterisation. The occurrence of any topic can form the basis for the information associated with the topic e.g. of course(s), lessons, units, musical genres/works/composers.

**Occurrence Role:** This is to express the context- dependent nature of each occurrence of the topic. One instance of an occurrence role can be the context-dependent remedial role of a learning unit according to a particular teacher applicable in certain delivery settings in respect of certain student or study levels etc.

**Topic Association:** The relationships between the topics are described using topic associations. The association represents the edges for the network and links the nodes based on their roles. This construct can for example determine the indicative learning units associated with a particular exercise, lesson or situation or the notes associated with a certain bar or piece of music in a certain genre or for a certain instrument etc. This works with the Occurrence Role value to provide multiple data-view possibilities including the encoding of the individualised pedagogic scenarios.

**Association Type:** Similar to topics, the associations can also be typed in respect of any shared properties. The ability to do typing of topic associations greatly increases the expressive power of the topic map, and therefore of the MaestrOnto-SCR. For example the association type can be used to characterise the dynamic nature of co-dependencies of learning units, notes, lessons, exercises, courses and even instruments playing in an orchestra at any time for the perfect rendition of any piece of music as it is played in a specific context. In a Topic Map overlaid with Bayesian Belief Networks, the probabilistic endorsement of the network links, thus effected, can be exploited for fuzzy reasoning and uncertainty management (e.g. as may be associated with music student's performance assessment).

**Association roles:** This is to define the role played by a topic within a given association. Another aspect of topic associations that is worth noting is that they are bi-directional. In MaestrOnto-SCR this can be exploited to enrich the causal or processual model for the association type such as that according to a particular pedagogic school, method, experience etc.

**Scope:** This is to confine an element to some domain boundaries (cf namespaces). This is similar to the use of namespaces in programming languages. By adding *scope* to the topic, we can limit the *visibility* of its properties at various levels, e.g. in MaestrOnto-SCR this can be used to designate sub-spaces, with a certain property x, e.g. lesson-sets, exercise-sets, notes-sets within a music piece, instrument sets within an orchestra etc with similar property x, pedagogic context boundaries/stages (e.g. B, I, A).

**Public Subject:** These are shared topics which may arise when two topic maps are being combined as may occur during the routine knowledge acquisition, sharing and lifecycle knowledge refinement. This concept is similar to global variables in programming languages. The need for these arises whenever topic maps are being combined; thus requiring any shared topics across the maps to be unified and referred to as public subjects so that they can be treated in the same manner. As with the scope, public subjects are useful in applying the global knowledge to any topic. In MaestrOnto-SCR this would allow graceful import-export/merging of the pedagogic knowledge e.g. amongst various teaching methods or music teachers/schools at various levels of abstraction e.g. to enable multi-model integrative refinement or contra-distinctive integrative reasoning to take place over different pedagogic units, music schools, orchestra performances, genres etc.

**Facets:** These are the name-value pairs that describe the topic elements as part of the metadata and thus complement the semantic parameterisation of topics. As can be seen the Topic Map offers a semantic-associative framework for representing and refining multi-faceted relationships knowledge. As such it is well-suited for the representation of PCK given the requirements of open-ness, dynamic update and merging of PCK information in a collaborative and evolving pedagogic environment. There is evidence which indicates that in certain circumstances e-learning may enable students to work at their own pace and personalise the direction of their learning. Potentially, the Internet is a resource which enables students to communicate and access data in different media forms. Optimistically, web-based technology may provide a learning infrastructure, with features considered vital within the constructivist theory of learning: namely, students belonging to a "community of learners", co-constructing knowledge using societal artefacts and tools (e.g. see figure below). These can form part of the metadata for each of the topics that can, in the context of the music pedagogy application domain, be also referenced by or linkable to SMR. As such the Facet will be the placeholder for some of the key context-dependent, and thus dynamically instantiable, parameters of the actual learning unit/exercise/ lesson or course content as it is authored and as it evolves.

An important innovation here is the engineering of *scope setter rules* operating on *facet values* to allow the contingent invocation of TSLs or individual (remedial) steps in a TSL chain and thus to mobilise structured but dynamic pedagogic delivery that is incrementally advanced as a wavefront of parallel forward projected contingent partial plans. Such partial plans can be described at any level to suit the pedagogic moment and/or the Pedagogic Dynamic Latency Window (PDLW). They can be a single (atomic) step or a whole non-linear hierarchical plan fragment (plan chunk or sub-net) in their own right; they can be projected uni-linearly or in parallel, partially overlapped or in complete overlay mode (requiring simultaneous, synchronous execution) with respect to other partial plans.

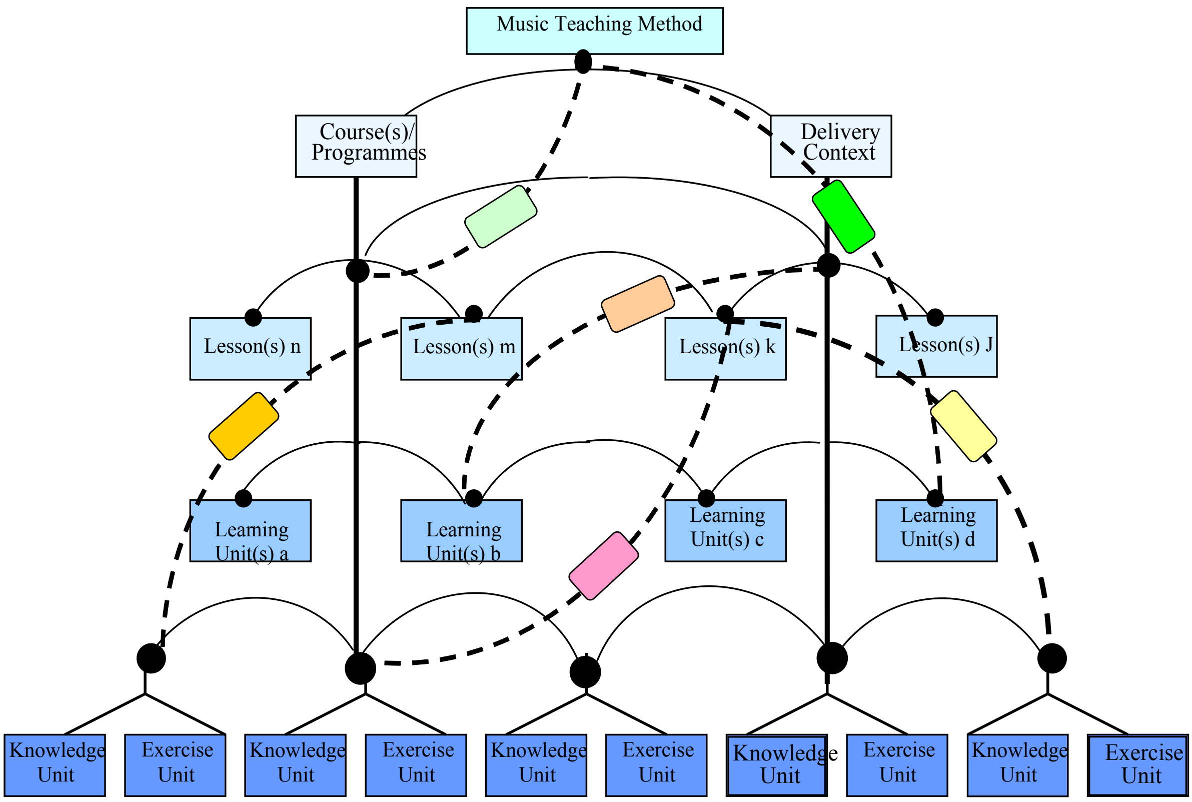



Figure 32: A schematic of one possible organisation of the ontological network for music pedagogy: MaestrOnto-SCR; dashed lines are to indicate example of PCK overlay for a particular situated pedagogy.

These can constitute alternative trajectories as a continuously streaming wavefront of teacher/learners negotiated PCK output pre-compiled and tentatively ready for contingent execution within the forthcoming (i.e. look-ahead DLW) up to the next epochal node (significant pedagogic juncture in progress assessment/appraisal) and in the context of pedagogic observations (assessments) since the previous *Epochal* nodes involving preceding DLWs ( look-back). In this way MaestrOnto-SCR can enable the pedagogic execution feedback to inform the data-driven adaptation of courses, lessons, exercises and learning units which thus remains sensitised to the delivery context and responsive to the contingent assessment epochs that are dynamically planned to suit the particular pedagogic setting e.g. B, I, A, theory/exercise, solo, group practice, harmony-building, composition, aural training for tonality-enhancing, within any pedagogic dynamic latency window– P-projections/moments, etc.

#### 8.1.2.2 Salient Features of the MaestrOnto-SCR Pedagogic Unit Schema and TSL to Support PFlow Control

According to constructivist theory, learning systems should provide learners with a wide range of services to assist and facilitate knowledge construction, rather than imposing a particular learning method on them. This is because it is impossible to model and maintain all the learning processes due to their variety. The learning object can be the fundamental unit of pedagogic processing in i-Maestro to construct units of learning out of more elementary objects. We note that lower granularity of learning objects is needed to provide the necessary flexibility to support constructivist learning particularly in music education.

Here we examine the features of the Pedagogic Unit (PU) Schema that has been designed to accommodate the representation of those knowledge engineering constructs found to be important in supporting the PFlow control so as to remain sensitive to the highly dynamic pedagogic context as it evolves, for instance, in music teaching and learning as a demonstration domain.

These constructs are explicitly or implicitly instrumental in teacher-learner pedagogic moments of decision making about how to navigate the pedagogic space and dynamically evolve and repair *Pedagogical Partial Plans* (PPPs). This is so as to arrive at individualised and situated pedagogic flow trajectories to pursue arbitrary learning objectives of the moment to satisfy personalised learning/assessment goals that can be teacher/leader initiated and/or mutually/self set at any stage.

For example our PM Generation and PFlow control support framework is designed to accommodate such notions as Pedagogic Epochs (PCK-based, assessment-driven milestones), Dynamic Latency Windows (DLWs) for PPP execution and review (look-back to any previous epoch) and forward projection (look-ahead toward tentatively set i.e. provisionally planned and contingent future epochs) in evolving dynamically contingent PPPs), plan repair and plan enactment, Pre-requisites (optional, mandatory), Post-conditions (dynamic incremental learning objectives/ outcomes), Knowledge Reporting Acts (KRAs), Knowledge Getting Acts (KGAs), Initial and Exit Conditions, Initial and Exit Modalities, Parallel, Overlapping, Overlaid and Nested Pedagogic Flows, Presentation and Augmentation Types/PPPs, Evaluation Types/ PPPs, (il)legal Flow Modes as a forward projection of Strongly/Weakly-coupled Pedagogic Units/PPPs, Contra-Indicated couplings/PPPs etc.

The overlap /overlay construct allows the representation of adhoc modes of synchronisation of pedagogic content that may belong to closely associated but distinct units as e.g. occurs in some forms of accompaniment with certain music exercises. The Figure below illustrates the highest level metadata descriptions of a pedagogic unit as defined for MaestrOnto-SCR. In this schema a pedagogic unit is viewed as comprising two distinct elements, namely a Knowledge Unit, and, an Exercise Unit and will also have PCK, evaluation and (meta) scaffolding-related representation elements (cf PPPs evolution patterns).

The design of the TSL is such that it is capable of exploiting the MaestrOnto-SCR representation of a pedagogic unit in order to invoke contingent *partial sequences* of pedagogic units that can be dynamically and statefully instantiated with maximum degrees of freedom in terms of iterative, recursive, re-entrant, unilinear parallel, overlaid and/or overlapped flow control involving any arbitrary conditions and *modalities of entry or exit* with respect to pedagogic unit invocations.

The proposed PM generation PFlow control support schema provides for a rich set of constructs for combining pedagogic units at any level in a number of configurations which in any event shall remain contingent and dynamically responsive to the pedagogic delivery context.

These constructs comprise of *control operators* and *chaining operators*. The control operators are to decide flow types such as situation assessment, iterative flow, re-entrant flow and recursion flow. The chaining operators are to decide chaining modes such as unilinear or sequential, parallel, grasshopper, butterfly, interleaved, overlapped. The overall flow can at any situation assessment point be taken forward through satisfying a condition which may relate to an *if, while or switch* type of condition.

The chaining of Pedagogic Material (PM) can be at any level of granularity of PM from PU dyads to triads to whole nested structures which can constitute lessons, courses or programmes of study. Such nested structures can be referred to as pedagogic plans, sub-plans or partial plans depending on their state of completeness or finalisation. The life cycle stages of such pedagogic structures whether they be complete plans for a course or programme, or a partial plan consisting of a tentative linking of several pedagogic units, would in any event have plan-time, execution-time and repair-time states which are distinguished by the degree of contingency or uncertainty of the nodes and their linkages in the plan.

As has been discussed already the aim should be to provide a repository of flexible and resilient pedagogic flow partial plans based on Pedagogic Content Knowledge (PCK). The run-time environment will allow the execution of such PCK-empowered partial plans to be dynamically responsive to the relevant delivery context as viewed by the participants and the chaining and flow control operators would allow the responsive modification of partial plans and evolution of their chaining together for best match making of the pedagogic delivery to the context. Accordingly the pedagogic unit schema comprises of the following representation sets.

Pedagogic Material (PM) may correspond to a Pedagogic Unit (PU), a course or a subject, a module, a lesson, or even a single learning activity such as a discussion to elaborate on some topic or in music how to play certain notes/bowing moves etc. Pedagogic Environment (PE) is the overall support platform made available to the teachers, comprising for example the i-Maestro PM generation and PFlow control support TSL Framework as well as PM object repositories (including client MaestrOnto-SCRs with PCK and profiles etc).

The PU schema comprises of six sets as follows, **Metadata, Content, Methods, Roles, Evaluation** (optional) and **(Meta)Scaffolding-PCK**.

**Metadata** essentially comprises of identifiers (pedagogic unit ID – PUID, title and keywords) and pedagogic objectives which are described in terms of their type, scope, description and the relationships with the pedagogic outcome of other pedagogic units in terms of whether or not such units constitute mandatory desirable or undesirable precursors or may or may not be contra-indicated in being combined with a particular PU.

An important descriptor in metadata is scope (which can be beginner, intermediate or advanced, and, delivery context which can be teacher or learner defined and match criteria which can be any number of context ref: value pairs/

**Content** comprises knowledge unit, exercise unit, and pedagogic resource. The knowledge unit and exercise unit are symmetrically represented under two sets of qualifiers namely conditions and communications. Important features within conditions for both knowledge units and exercise units are initial conditions and initial modalities which can be static or dynamic. Communications describe the set of knowledge Getting Acts (KGA) and Knowledge Reporting Acts (KRA) or any other flags which may need to be set in order to ensure stateful control based on full semantic integrity, semantic integration, persistence and therefore continuity of sessions that may be distributed in space and time.

Pedagogic resource is described in terms of the pedagogic content, communication and tool objects each with its own metadata and accessibility information.

Pedagogic **Methods** are viewed essentially as PFlows with a structure ID and contingent invocation and linking control information for iterative, recursive or re-entrant invocation in various configurations (i.e. chaining modes such as uni-linear, parallel, grasshopper, butterfly, interleaved, overlapped) with respect to any other pedagogic unit or partial plans.

It is important to note the significance of these chaining modes in terms of music pedagogy for example a partial or full accompaniment can be referred to as overlapped with various start and stop triggers which can be invoked by the situation assessment operators in order to reflect the intermittently overlapped configuration requirement of musical effects. These can be referred to for the purpose of the SMR TSL for epochally triggered content insertion or content overlays etc. Equally interleaved (alternate insertion) and grasshopper (skip every so many entities/epochs) are self-evidently equally applicable at the SMR level of exercise generation just as they are applicable to interleaved or grasshopper chaining of individual pedagogic units or whole nested pedagogic partial plans.

Clearly such contingent configurations are particularly suited to PM Generation and PFlow control support in music exercise generation and pedagogic music authoring as well as judicious and responsive deployment of augmentation (e.g. gesture control) and evaluation or assessment effects.

Under **Roles**, specific optional entities such as student, tutor, augmentor and ECA (Embedded Conversation Agent – Avatar /Learning ebuddy/ e-mentor) are distinguished with the learner or student being the only mandatory entity.

As for **Evaluation** or assessment which is optionally available. Various degrees of ICT or teacher mediation are distinguished as in partially mediated, fully mediated or unmediated.

Finally under (**Meta)Scaffolding-PCK** we include descriptors for partial pedagogic plans, or P-plans which are nested activity structures, pre-compiled and particularised to suit particular contexts. Naturally this can be exploited to create PCK empowered partial plans for example problem-specific remedies or subject specific strategies known by a teacher to be particularly suited to classes of learning situations, particular learners or learner clusters. Such matching of prepared partial plans to particular delivery contexts is a natural evolutionary maturation of pedagogic skill which can be exploited through articulaton and formalisation of PCK knowledge within *communities of practice* as much as possible and accordingly provision has been made for optional designations of closely-coupled, weakly -coupled or ill-coupled pedagogic partial plans to be referenced as such and to become available for PCK knowledge sharing and constructivist review in the blight of feedback to support evolutionary organisational/self learning about learning for the benefit of all actors and communities.

In terms of Pedagogic entity types the language constructs amount to a representation of seven types of objects namely metadata, content, methods, evaluations, case studies and pedagogic partial plans.

The following figures illustrate the flow control types and the Pedagogic Unit (PU) Schema:

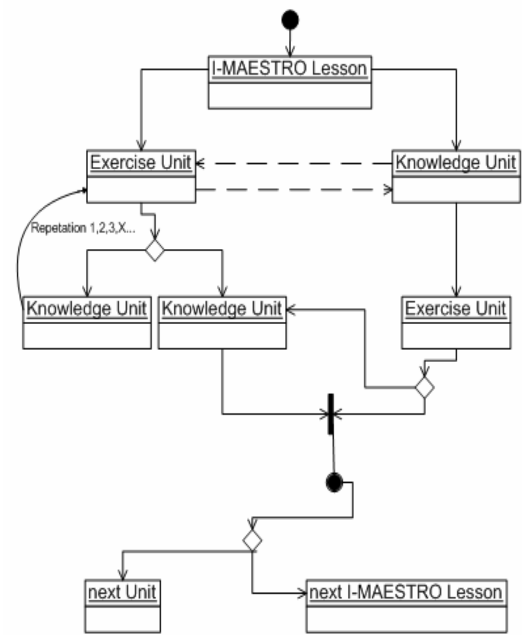



Figure 33: pedagogic flow with contingent action

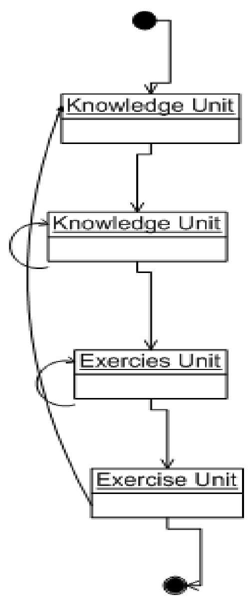



Figure 34: Pedagogic flow with iteration

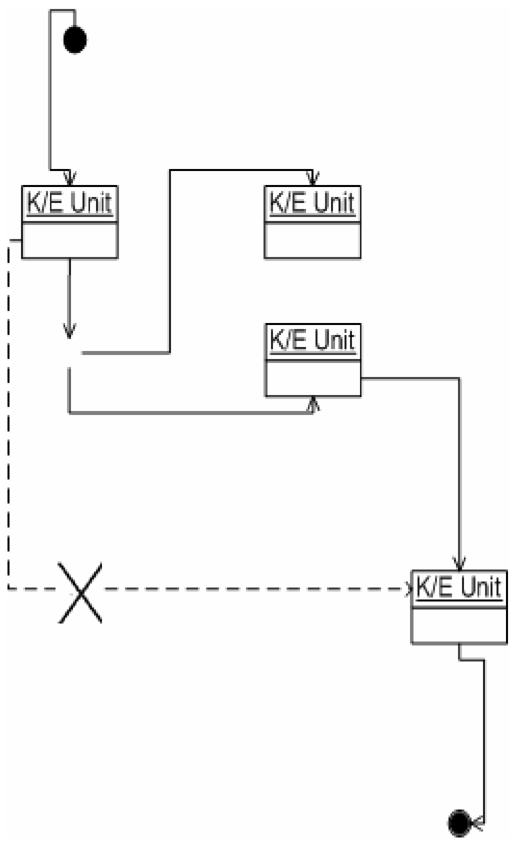



Figure 35: Pedagogic flow - example pathways

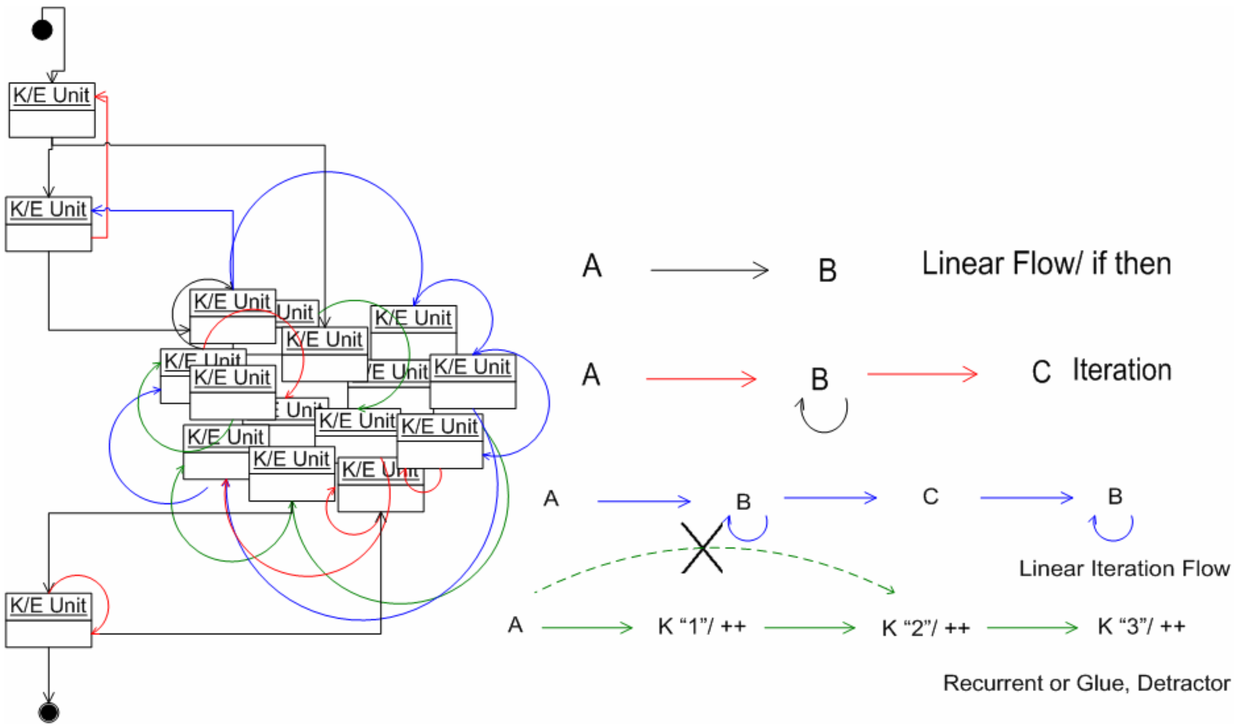



Figure 36: Schematic of the various contingent pedagogic flow control pathways combined

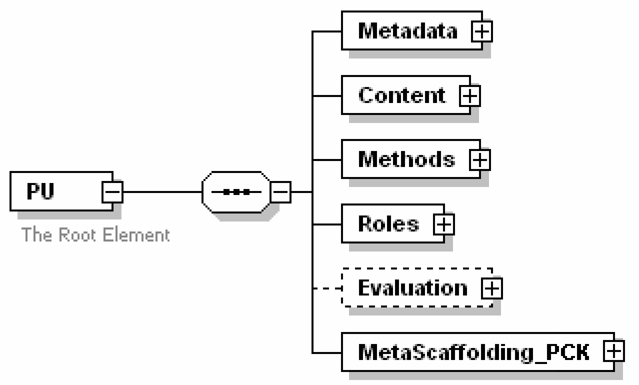



Figure 37: Pedagogic Unit Schema Top Level Structure

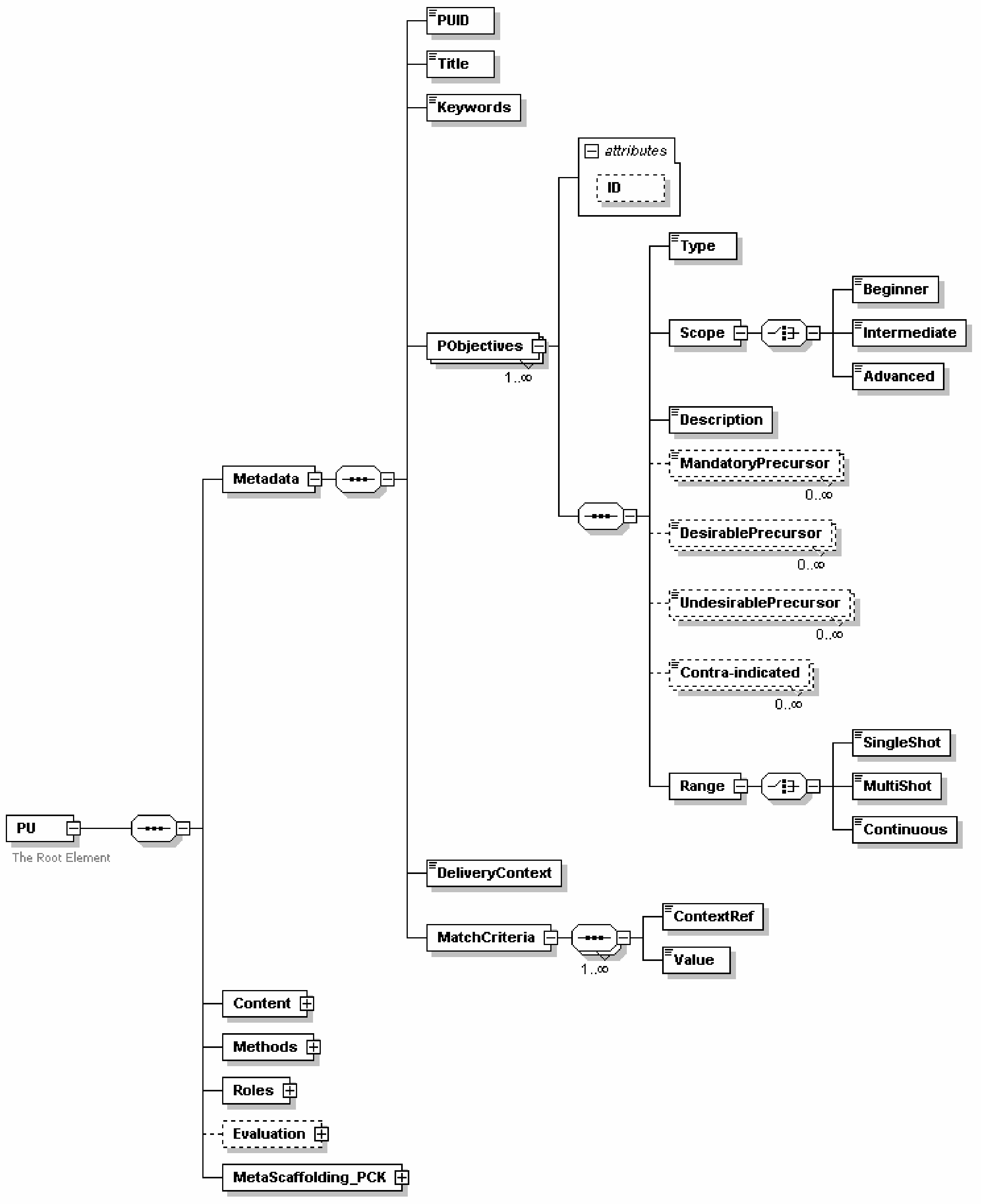



Figure 38: PU Schema Metadata

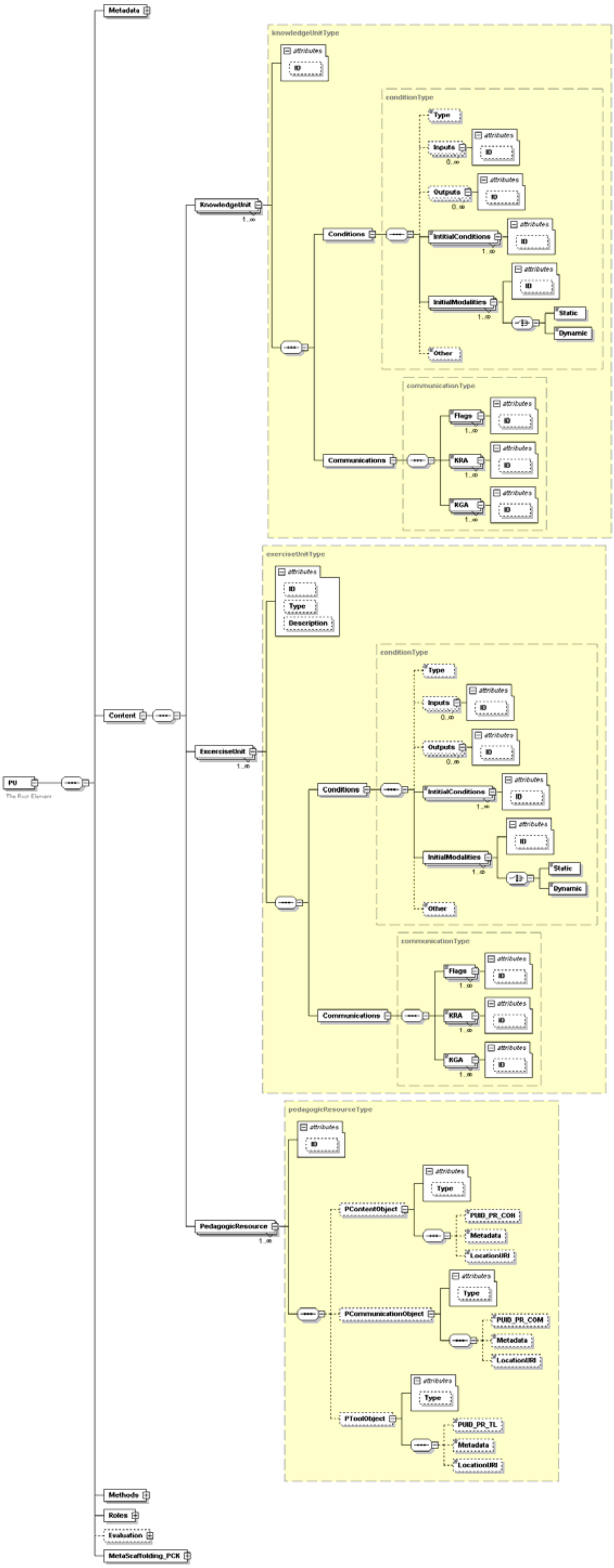



Figure 39: PU Schema Content

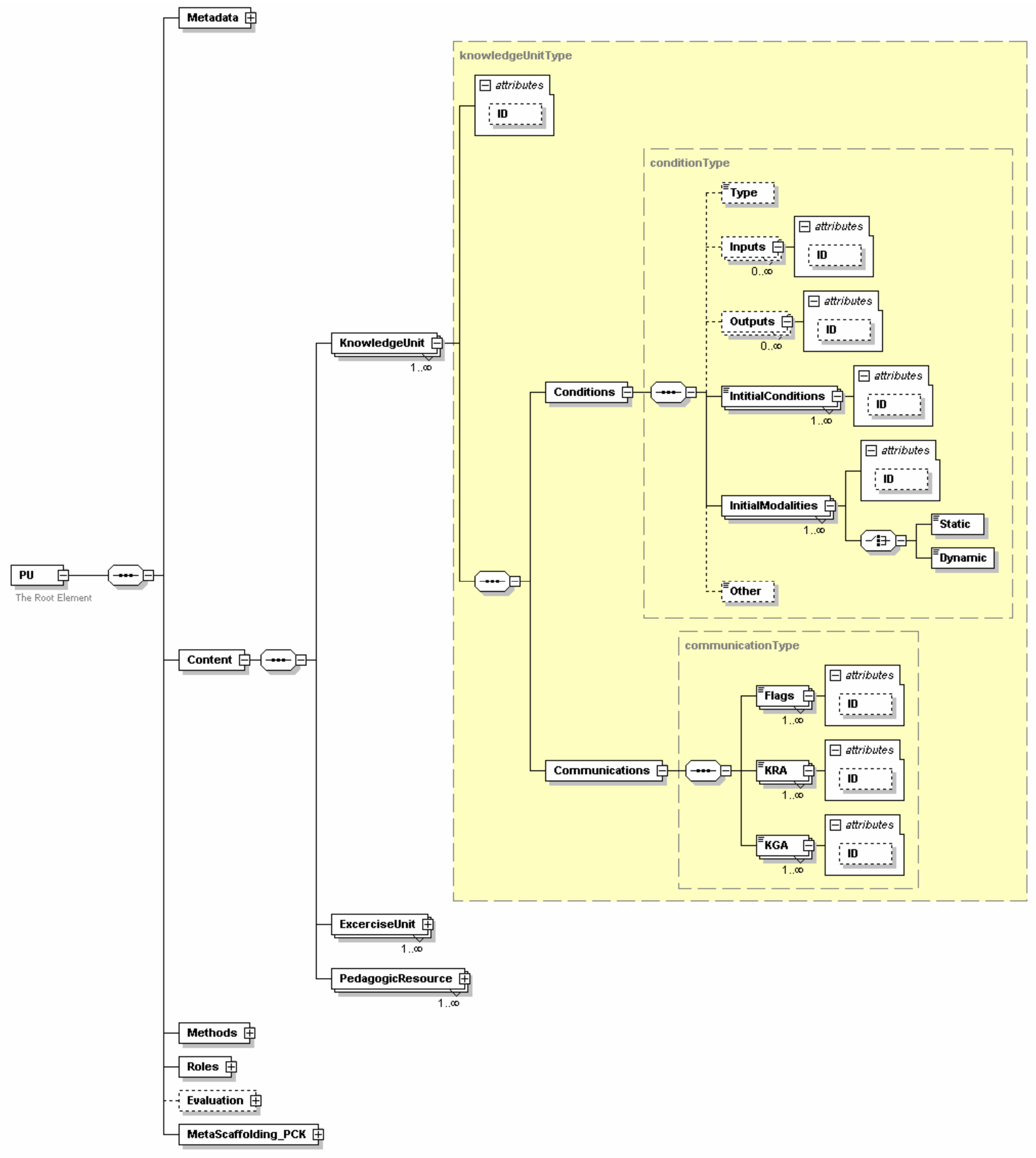



Figure 40: PU Schema Content Knowledge Unit

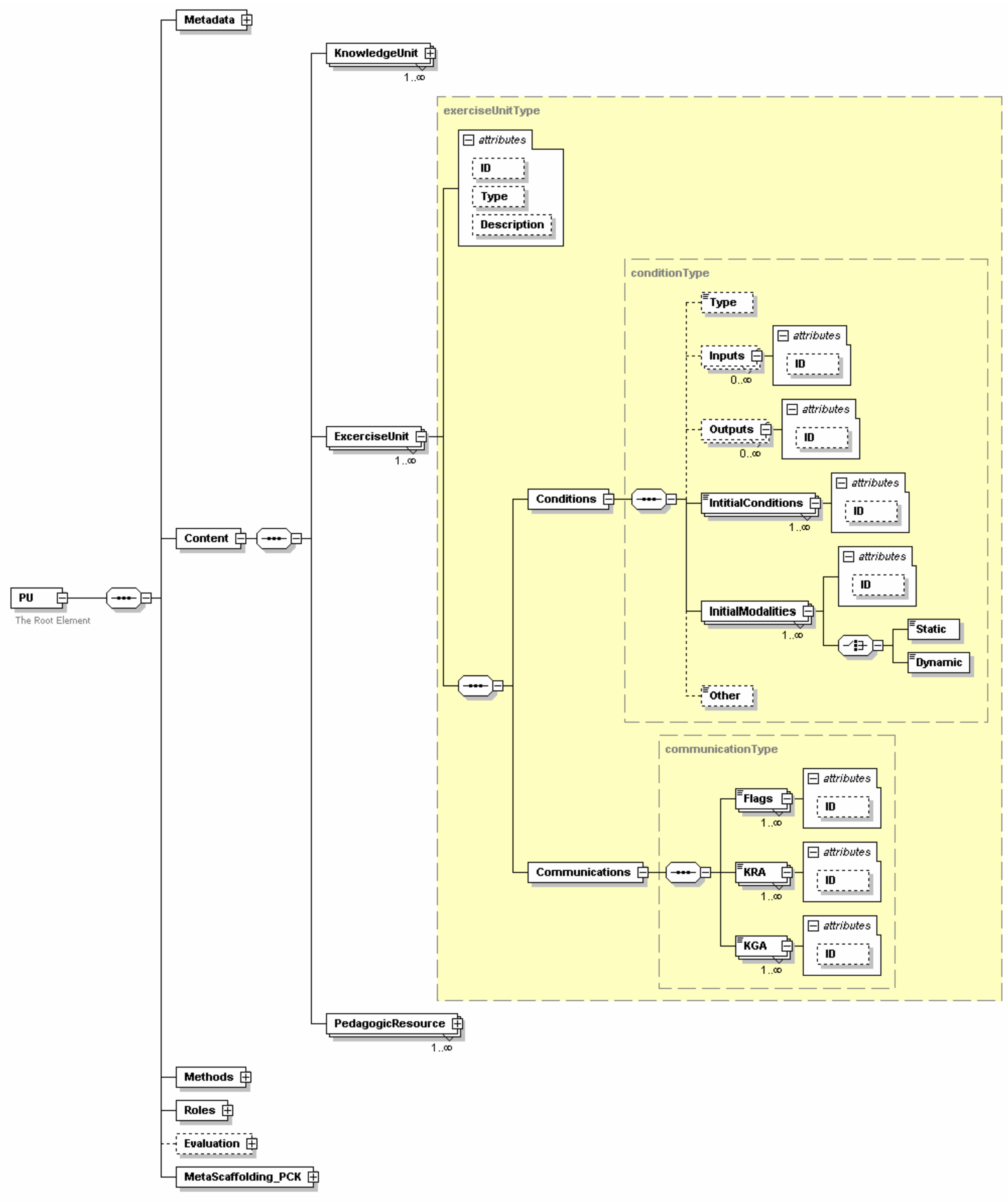



Figure 41: PU Schema Content Exercise Unit

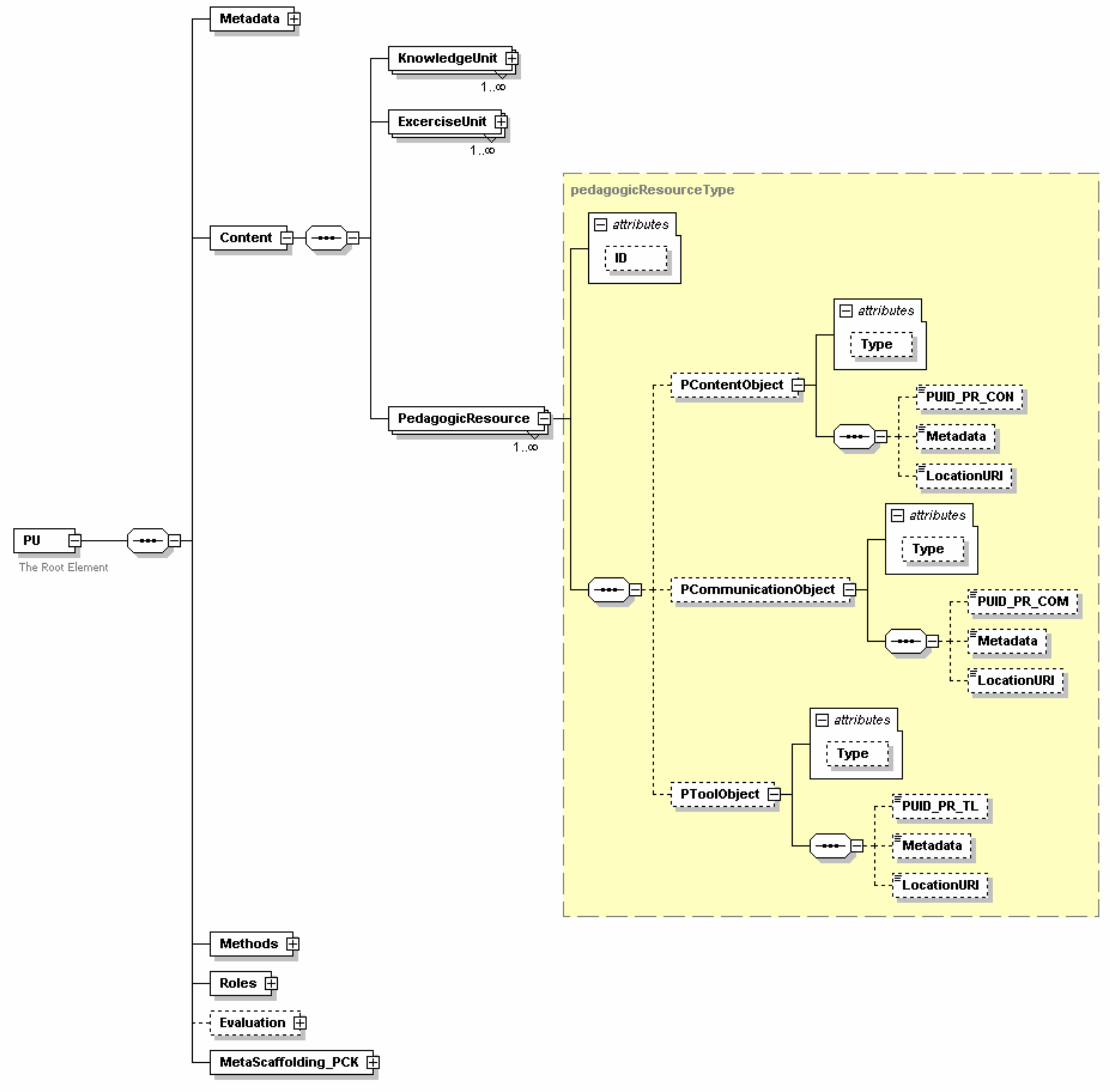



Figure 42: PU Schema Content Pedagogic Resources

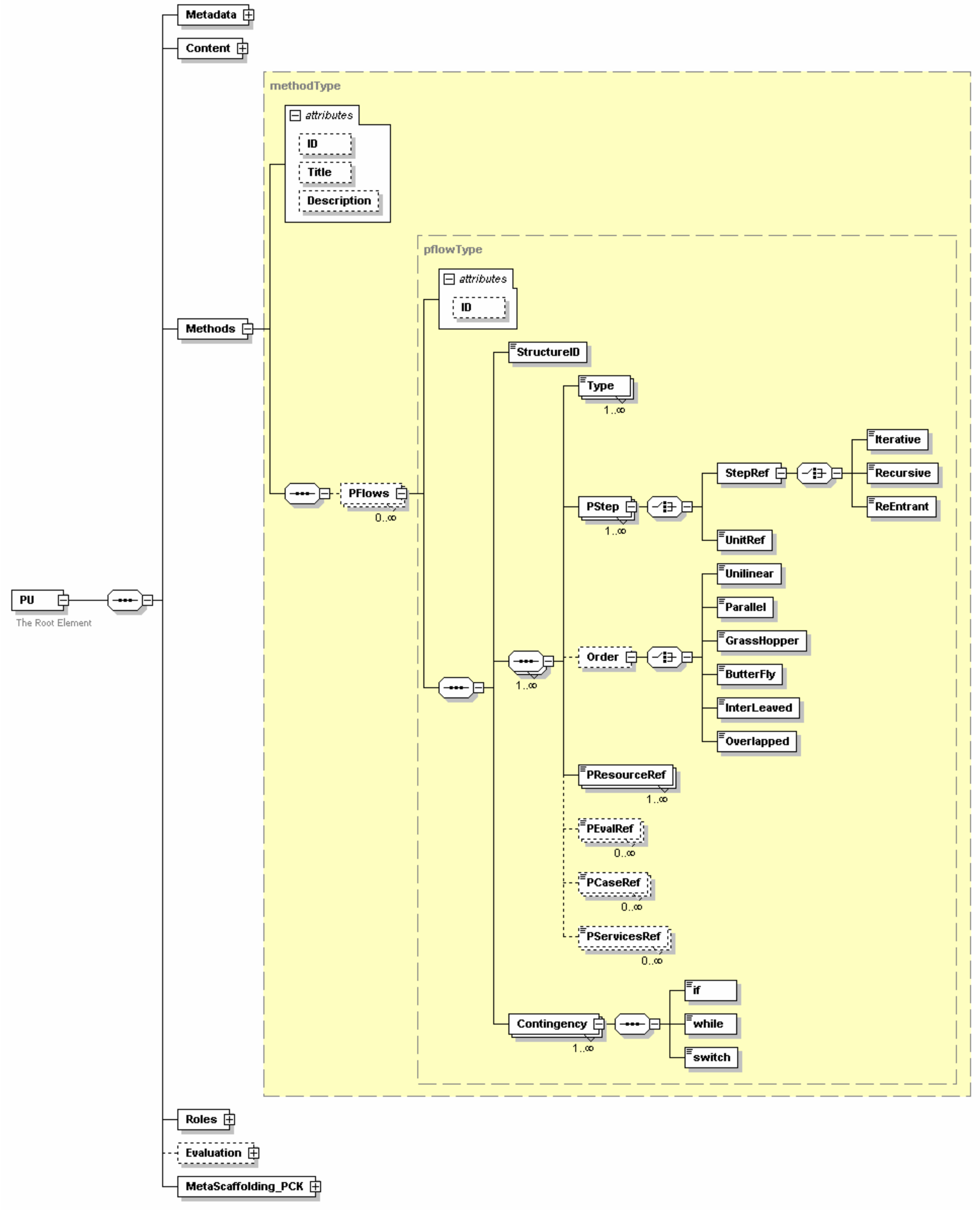



Figure 43: PU Schema Methods

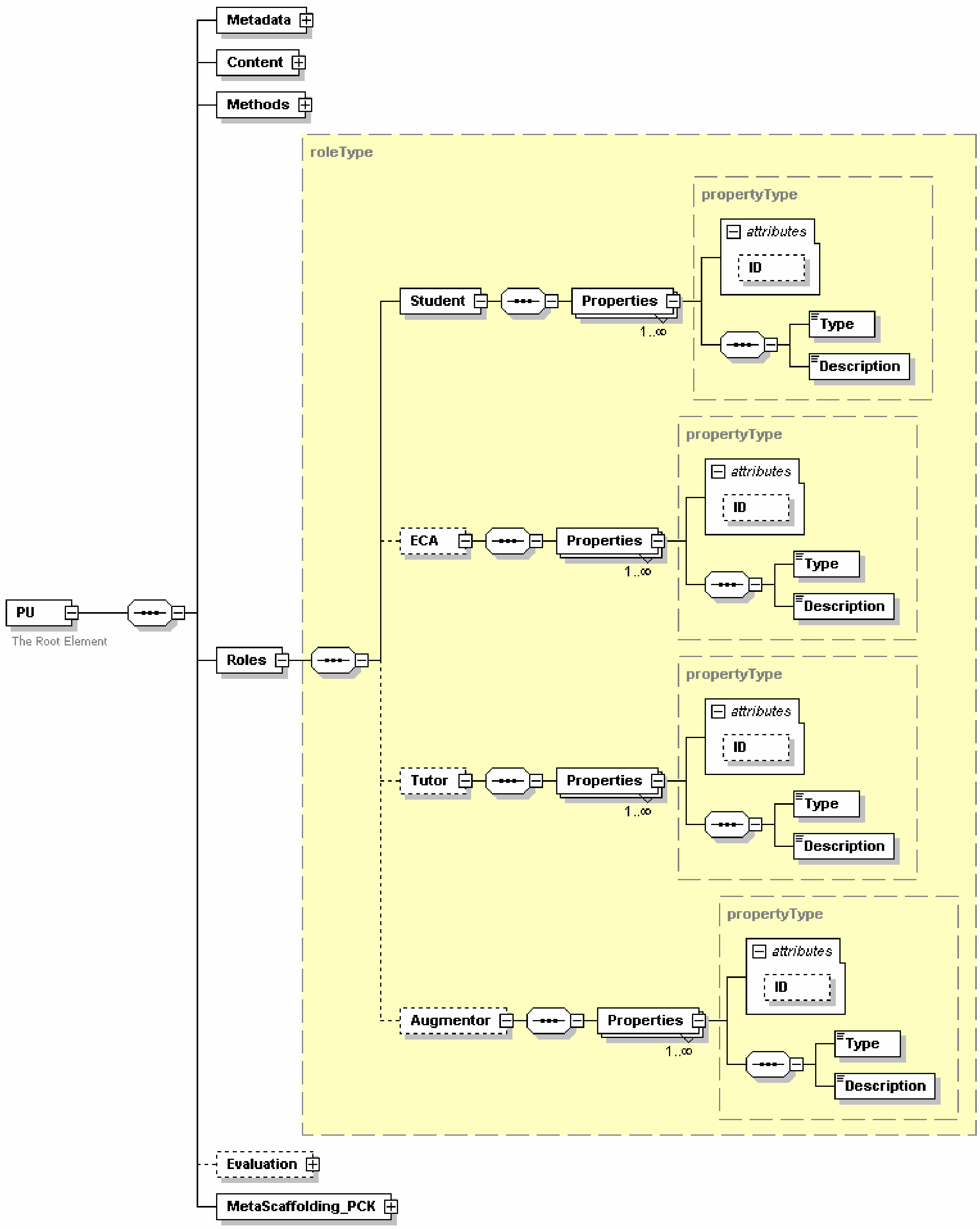



Figure 44: PU Schema Roles

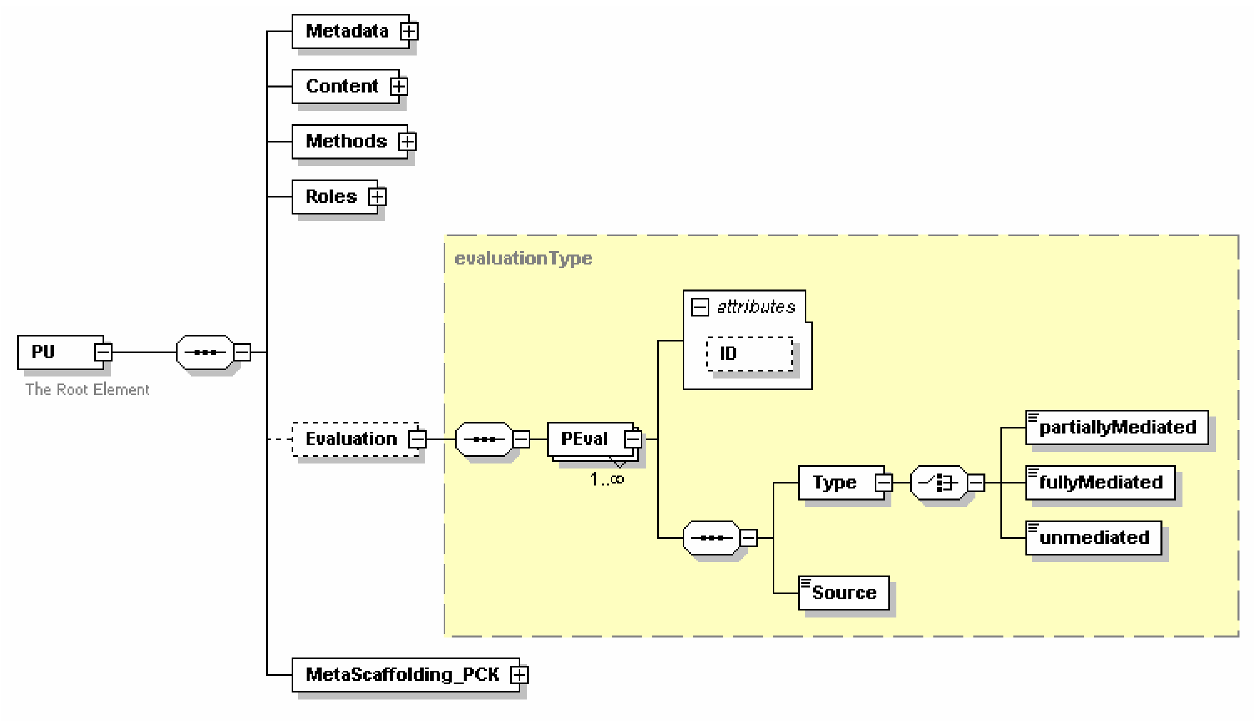



Figure 45: PU Schema Evaluation

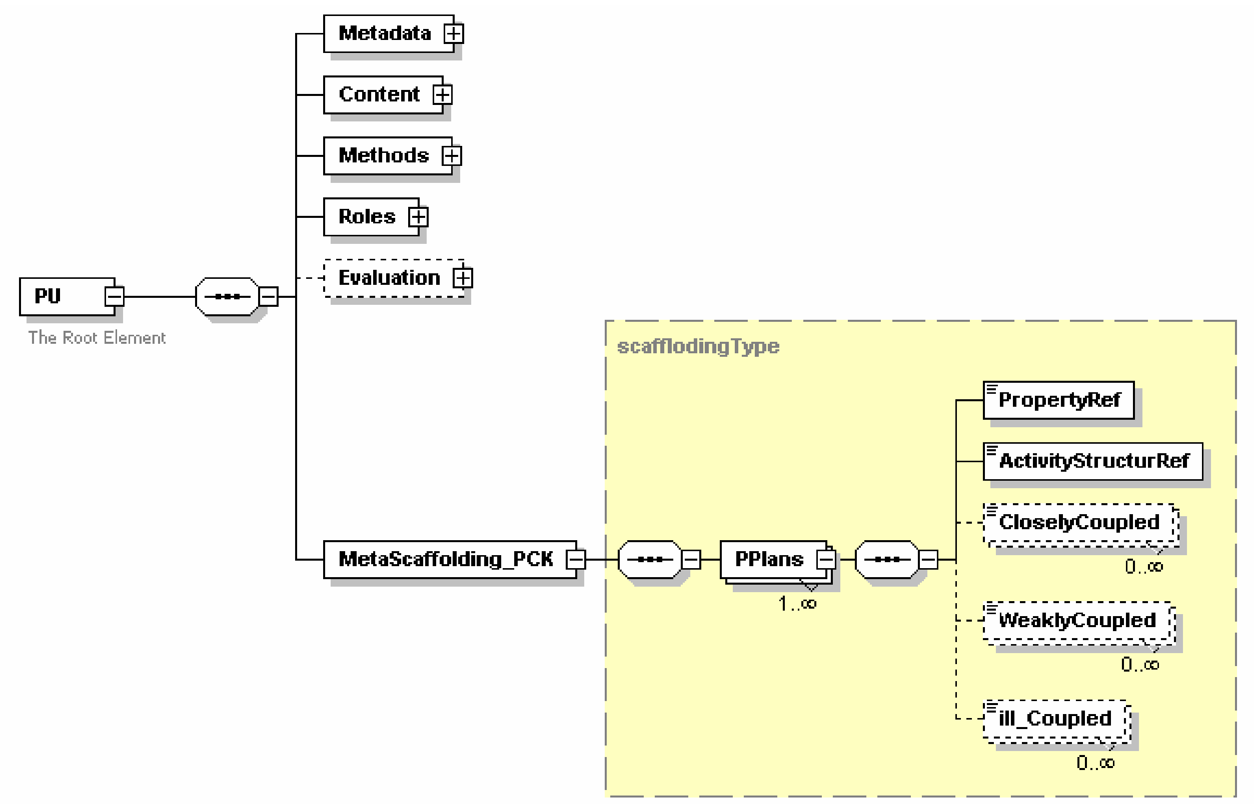



Figure 46: PU Schema (Meta)Scaffolding-PCK

# 9. TSL for Symbolic and Practical Training

The Training Specification Language for music training is to model and support the pedagogic flow control modalities that particularly occur in music training. We have seen that in linear and simple exercises the sequence of actions of the exercise can be modelled with some standard model such as the IMS. Unfortunately, in learning and teaching music simple linear sequences are rare especially once the pupil is passed the first few elementary lessons. Thus a formalisation of pedagogic material generation and flow control support based on simple sequencing would be inadequate here. In previous sections we have already reviewed some of the latest work exploiting the EML (Educational Modelling Language) that has formed the basis of our proposed approach to the design of a Training Specification Language for i-Maestro that is motivated by formal EML in order to deliver the Control, Packaging and Presentation Flow Control Management Requirements that are particularly implicit for the I-Maestro Music Authoring and Lesson Packaging domain.

## 9.1 Language Requirements

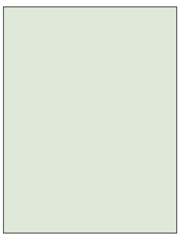
Stateful control structures are required to support the following contingent flow control requirements that as we have seen are part of the normal pattern of the highly dynamic i-Maestro pedagogic delivery context

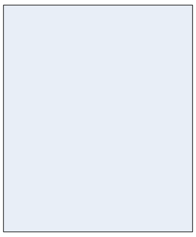
i. **Uni-linear (default) Sequencing,**
ii. **Conditional branching,**
iii. **Hierarchical nesting**
iv. **Recursion,**
v. **Iteration,**
vi. **Re-entrancy.**
vii. **Overlay**

These typically require the representation language to provide flow triggers modelling to allow the stateful, control of contingent invocation of pedagogic objects and flow paths based on an efficient and effective representation of objects, context s and flow types as already derived for the Pedagogic Unit Schema. Thus the TSL has to allow for contingent iterative, re-entrant, recursive and flow control.

This can be illustrated and described by the domain requirements based on some prototypical example scenarios of flow control to support music training at the Beginner (B), Intermediate (I) and Advanced levels.

**<u>Basic Violin Teaching Scenarios (Beginner, Intermediate, Advanced)</u>**


= Input/ action (e. g. pupil)

 = Reaction/ analysis (e. g. teacher)

F: Failure

S: Solution/ Suggestion

**Basic Linear Flow:**

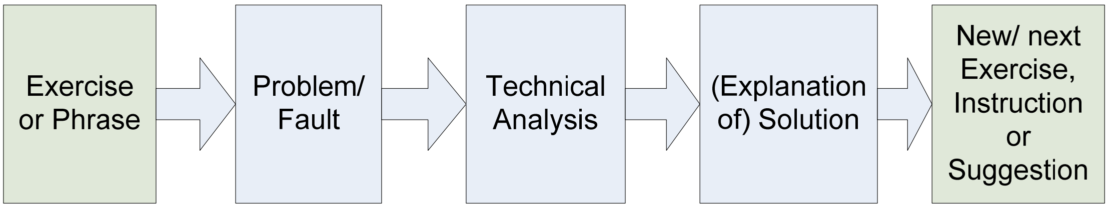



Figure 47: general Problem-based pedagogic flow

**<u>Concrete Example Beginner Level:</u>**

Exercise: Playing open string

Problem:

F: Scratchy Sound

Possible Suggestions/Solution of the Problem:

S: Repeat it with more bow speed

**<u>Concrete Example Linear Flow:</u>**

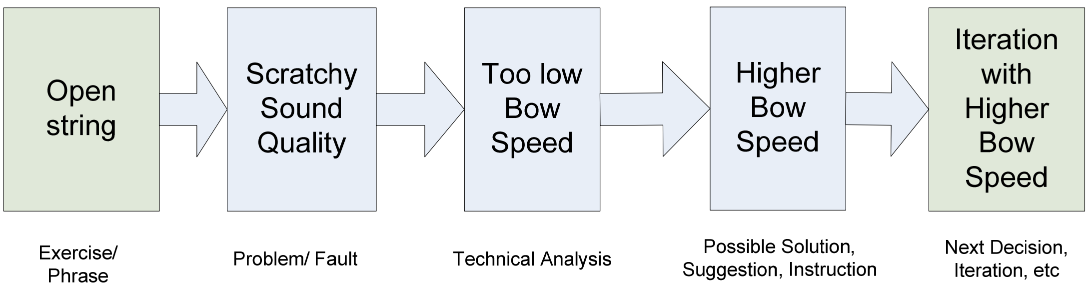



Figure 48: Problem-based linear pedagogic flow – Beginner Level

**Concrete Example Intermediate Level:**

Exercise: Playing a Sequence of fast Notes

Problem:

F: Irregular sequence of the notes

Some Possible Suggestions/Solutions of the Problem:

S: Repeat it with decreased tempo

**Concrete Example, Linear Flow:**

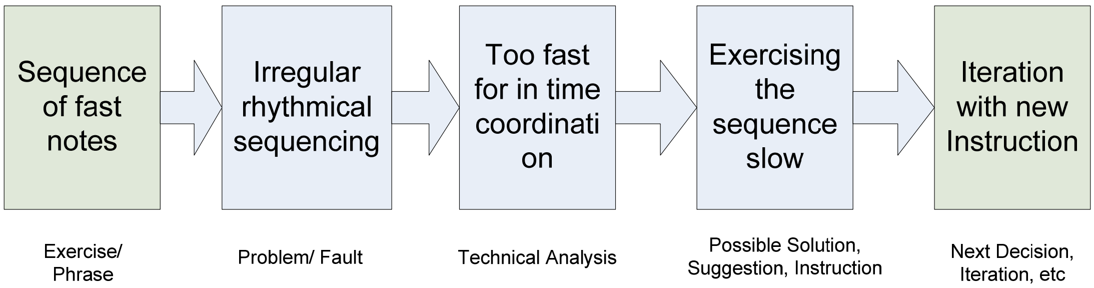



Figure 49: Problem-based linear pedagogic flow – Intermediate Level

**Concrete Example Advanced Level:**

Exercise: Articulation of a specific Tone (e. g. aggressive and loud) of a Note in a Violin Concert

Problem:

F: Wrong Articulation

Some Possible Suggestions/Solutions of the Problem:

S: Repeat it with correct acceleration (attack) of the bow

**Concrete Example Linear Flow:**

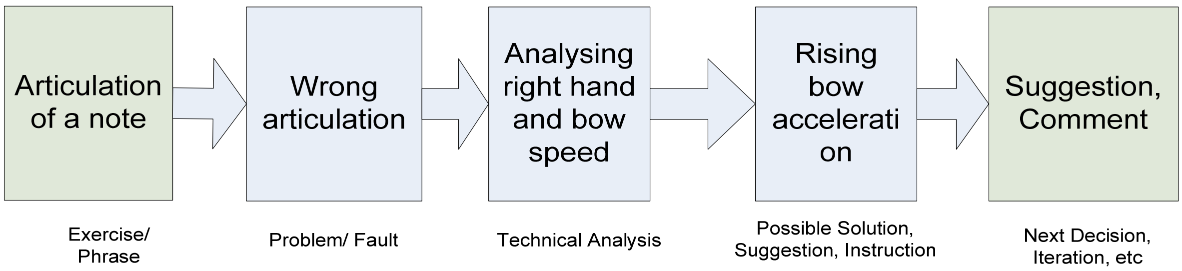



Figure 50: Problem-based linear pedagogic flow – Advanced Level

## 9.2 Language Specification for Flow Control support

With reference to the above domain levels (B, I, A), working from a pedagogic knowledge base as mediated by MaestrOnto-SCR, the appropriate pedagogic flow control structures to fulfil the language requirements so far discussed, as applied to the above examples for illustration, are as follows:

**Example Beginner Level Lesson**

| |
|---|
| Initial Delivery Context<br><br>selected PUID = [pitch] = name Z<br><br>[one to one] = teaching/ learning situation<br><br>[static P0, P1, Pn] // pre requisites, initial flags<br><br>[P0 = Beginner Level]<br>[P1 = Age between 8 to 20]<br>[P2 = Basic Feedback enabled] // personal feedback of teacher<br>[P3 = Advanced Feedback disabled] // feedback of gesture recognition,<br>// exercise generator, etc.<br>[P4 = Course X, Y is done, Lesson Z is done] |
| Body<br><br>Sequence:<br><br>1. Execute a Pedagogic Structure<br><br>[initial run-time Condition]<br><br>[P0 = Pupil is ready to play]<br>[P1 =Violin is in the right position]<br>[P2 = Bow is on the string]<br><br>[exit Condition]<br><br>[P0 = Pitch is right, not too high, not too low]<br>[P1 = Quality of sound is good]<br>[P2 = Hand is in right Position] |

2. Initial Modality [static P0, P1, Pn, dynamic P0, P1, Pn] // teacher asking pupil to
// play

Basic Feedback: enabled
Static
[P0 = Pupil is playing]
[P1 = 1. Finger, 1. Position]
[P2 = String A]

Dynamic Modality // teacher's PCK-based intervention

[P0 = Quality of sound]
[P1 = Position of the thumb]

Advanced Feedback: disabled

3. Learning action content (lac), e.g. input from teacher, analysing the input of the pupil

4. Conditions, Assessment [if, switch, while]
[*if* position of hand is wrong *then* Unit X from Lesson Y] // select another lesson
[*if* pitch is right *then* next Unit] // select next unit
[*if* pitch is too low *then* repeat same unit] // same Unit again
[*while* pitch is too low && counter <6 count ++] // up to 6 repetitions same
// unit

EXIT FLAG SETTING [static P0, P1, PN]

[P0 = Beginner Level]
[P1 = Age between 8 to 20]
[P3 = Course X, Y is done, Lesson Z + 1 is done]

**General Basic Description and Skills**

Initial Delivery Context

selected PUID=[pitch] = Name of lesson

[one to one] = Teaching/ Learning situation

[static P0, P1, Pn] // Pre requisites, Entering Flags

[P0 = Beginner Level 1]
[P1 = Age between……]
[P2 = Basic Feedback enabled] // personal Feedback of teacher
[P3 = Advanced Feedback disabled] // feedback of gesture recognition,
// exercise generator, etc.
[P4 = Course X, Y is done, Lesson Z is done]

---

Body

Sequence:

2. Unit

[initial Condition]

[P0 =…]
[P1 =…]
[P2 =…]

[exit Condition]

[P0 =…]
[P1 =…]
[P2 =…]

2. Initial Modality [static P0, P1, Pn, dynamic P0, P1, Pn] // teacher asking the pupil to
// play

Basic Feedback: enabled
Static

[P0 =…]

[P1 =…]

[P2 =…]

Dynamic Modality // PCK-based intervention from teacher

[P0 = …]

[P1 = …]

Advanced Feedback: enabled // technology based feedback like // gesture control

3. Learning action content (lac), like input from teacher, analysing the input of the pupil

4. Conditions, Assessment [if, switch, while] //several examples, only 1 decision // is possible

[*if … then* Unit X from Lesson Y] // other lesson

[*switch …* ] // more than one choice like next Unit or other lesson …,

[*if … then…* ] // same Unit again

[*while …* && counter <n count ++] // up to n repetitions same // unit

EXIT FLAG SETTING [static P0, P1, PN]

[P0 = Beginner Level]

[P1 = Age between …]

[P3 = Course X, Y is done, Lesson Z + 1 is done]

**Fast Notes**

Initial Delivery Context

select PUID=[fast notes] = Name Z

[one to one] = Teaching/ Learning situation [static P0, P1, Pn] // Pre requisites, Entering Flags

[P0 = Intermediate Level]
[P1 = Age between 8 to 20]
[P2 = Basic Feedback enabled] // personal Feedback of teacher
[P3 = Advanced Feedback disabled] // feedback of gesture recognition,
// exercise generator, etc.
[P4 = Course X, Y is done, Lesson Z is done]

---

<u>Body</u>

Sequence:

3. Unit

[initial Condition]

[P0 = pupil is ready to play]
[P1 =Violin is in the right position]
[P2 = Bow is on the string]
[P3 = Kreutzer Etude Nr 3 is prepared]
[P4 = Measure 4 – 8]

[exit Condition]

[P0 = fast notes are right in time]
[P1 = quality of sound is good]
[P2 = Hand is in right Position]

2. Initial Modality [static P0, P1, Pn, dynamic P0, P1, Pn] // teacher asking the pupil to
// play

Basic Feedback: enabled
Static
[P0 = pupil is playing]
[P1 =measure 4 - 8]
[P2 =Kreutzer Etude Nr 3]

Dynamic Modality // teacher's PCK-based intervention

[P0 = quality of sound]

[P1 = Position change of the left hand]

Advanced Feedback: disabled

3. Learning action content (lac), like input from teacher, analysing the input of the pupil

4. Conditions, Assessment [if, switch, while] //possible Examples

[*if* position change of hand is to slow *then* Unit X from Lesson Y] // other // lesson

[*if* timing and sound is right *then* next Unit] // next Unit

[*if* speed is too low *then* repeat same unit] // same Unit again

[*while* speed is too low && counter <6 count ++] // up to 6 repetitions same // unit

EXIT FLAG SETTING [static P0, P1, PN]

[P0 =Intermediate Level]

[P1 = Age between 8 to 20]

[P3 = Course X, Y is done, Lesson Z + 1 is done]

**Advanced Level**

Initial Delivery Context

select PUID= [Articulation] = Name Z

[one to one] = Teaching/ Learning situation

[static P0, P1, Pn] // Pre requisites, Entering Flags

[P0 = Advanced Level]

[P1 = Age between 18 to 30]

[P2 = Basic Feedback enabled] // personal Feedback of teacher

[P3 = Advanced Feedback disabled] // feedback of gesture recognition,

// exercise generator, etc.

[P4 = Course X, Y is done, Lesson Z is done]

<u>Body</u>

Sequence:

4. Unit

[initial Condition]

[P0 = pupil is ready to play]

[P1 =Violin is in the right position]

[P2 = Bow is on the string]

[P3 = Mozart Violin concert A Major]

[P4 = First Movement]

[P5 = Measure 104 to 105]

[exit Condition]

[P0 = Articulation is discussed]

[P1 = quality of sound is good]

2. Initial Modality [static P0, P1, Pn, dynamic P0, P1, Pn] // teacher asking the pupil to

// play

Basic Feedback: enabled

Static

[P0 = pupil is playing]

Dynamic Modality // teacher's PCK-based intervention

| |
|---|
| [P0 = changing of the position]<br>[P1 = Position of the hand]<br><br>Advanced Feedback: disabled<br><br>3. Learning action content (lac), like input from teacher, analysing the input of the pupil<br><br>4. Conditions, Assessment [if, switch, while]<br>[*if* articulation is wrong *switch* compare Unit X from Lesson Y or Lesson Y4 or Unit U5 etc.] // other lesson<br>[*if* articulation is right *then* next Unit] // next Unit<br>[*if* articulation is wrong *then* repeat same unit] // same Unit again |
| <u>EXIT</u> FLAG SETTING [static P0, P1, PN]<br><br>[P0 = Advanced Level]<br>[P1 = Age between 18 to 30]<br>[P3 = Course X, Y is done, Lesson Z + 1 is done] |

# 10. Integration of the PM Generation and Flow Control Support Framework with the MAX/MSP Support Environment

The PFlow control support framework (MaestrOnto-SCR, PU Schema and TSL) integration with the MAX/MSP environment has been implemented as a first Prototype. The Screen shots of the top level navigation panel for the i-Maestro Authoring Tool and the Pedagogic material generation and processing module accessed through the i-Maestro Authoring Tool navigation panel are presented below after a description of the tools tips for the 6 top level buttons. Clearly the PFlow Control Support Framework can be used for generation of any pedagogic material at any level of granularity including course, lesson, Pedagogic units (Knowledge Units (KU) and Exercise Units (EU)) generation.

## 10.1 Tool Tips for I-MAESTRO Authoring Tool UI MAX/MSP Patch

**PM Views:**
Open pedagogic material (access or set up a new file e.g. KU - EU) - save or delete any pedagogic material - play - display - execute - view metadata etc.

**PM Edit:**
Edit KUs - EUs - edit metadata -includes support for undo, cut and paste etc - standard multimedia editing operations.

**PCK-Profiling:**

Set up profiles - IDs - privileges for user groups - integration environment for linking different pedagogic units and teaching - learning contexts.

**PE Resourcing:**
Select and set up appropriate teaching and learning resources (objects - channels and tools) linked to a pedagogic unit (e.g. to an exercise unit generation) or activity structures generation.

**(Meta)Scaffolding:**
Pre-compiling and chaining specific (nested) chains of pedagogic activity saved/accessed as partial pedagogic plans linked to other chains - pedagogic units and contexts.

**Evaluation:**
Evaluating and assessing pedagogic material and delivery context (i.e. PCKs) for both teaching and learning at student, group and strategy levels.


Figure 51: Top level navigation panel for the i-Maestro Authoring Tool

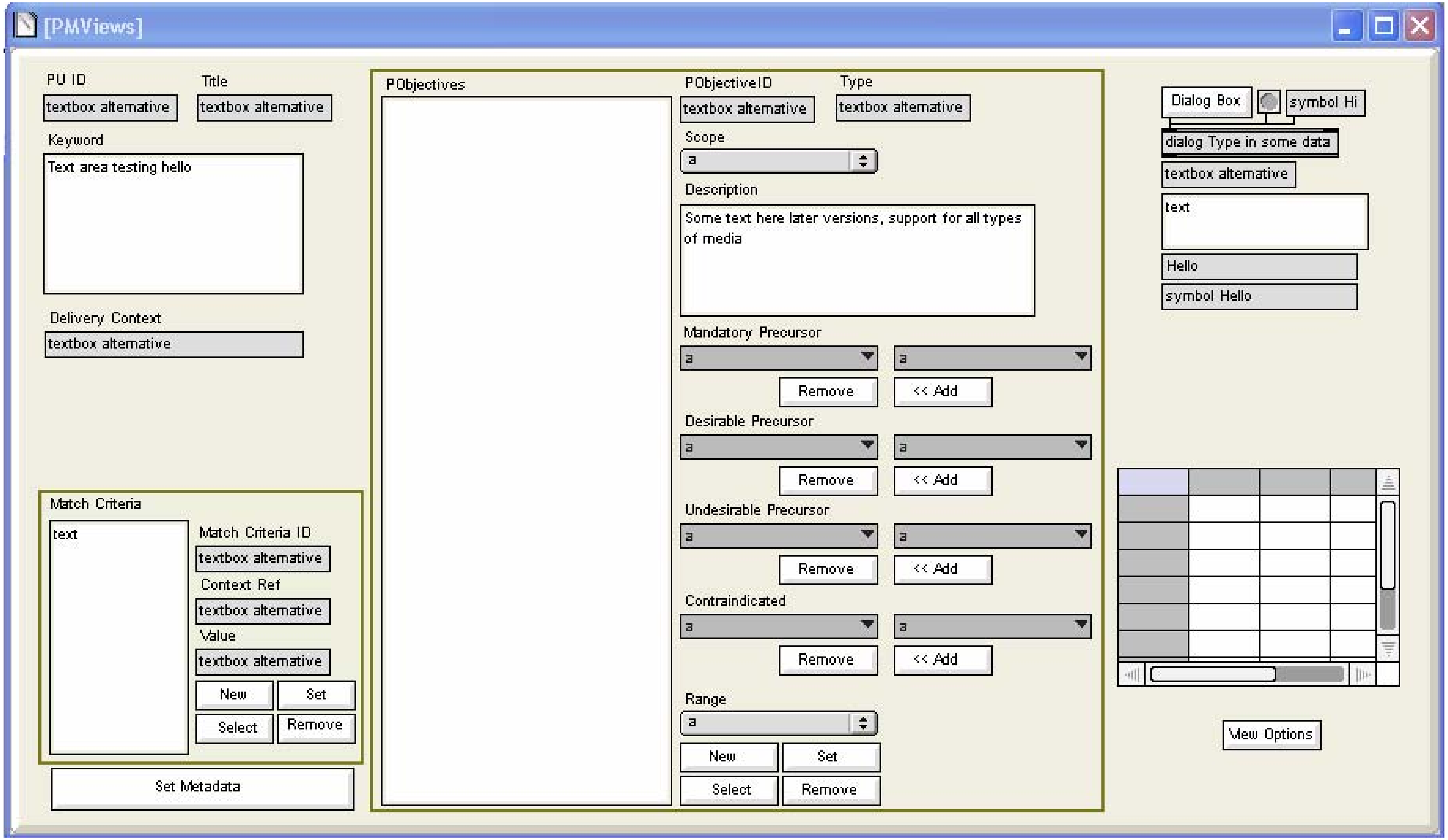



Figure 52: Pedagogic material generation and processing module accessed through the i-Maestro Authoring Tool naviagation panel

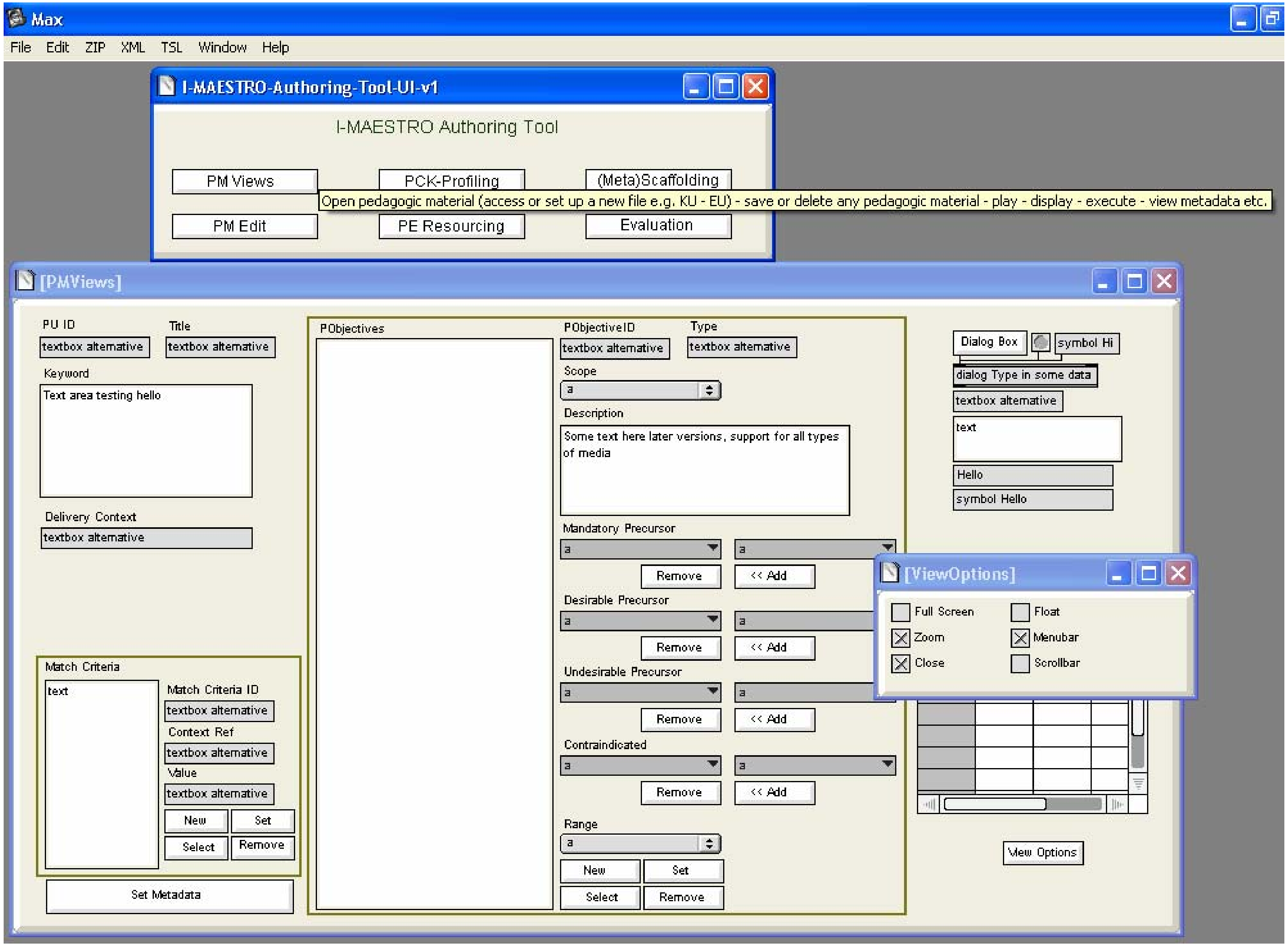



Figure 53: MAX/MSP Patch for the i-Maestro Authoring Tool displaying the main navigation panel with user tool-tips and the pedagogic material generation and processing module (the view options module enables manipulation of window view features)

# 11. Conclusion

This report has dealt with the analysis of various pedagogic flow models and reviewed the state of the art re SCORM, IMS, and EML. . It has formally established the choice of the multimedia authoring environments to provide the underlying multimedia editing functions for the iMaestro authoring tool i.e. MAX/MSP.

An innovative generic i-Maestro Framework for Pedagogic Material representation, generation and flow control support has been devised, implemented and integrated with the Max/MSP music authoring tool to serve as a first prototype of the i-Meastro Music Authoring, Exercise Generation and Flow Control Support Tool.

The i-Maestro Pedagogic Material Generation and Authoring Framework thus established deploys an innovative mediating representation (i-MaestrOnto-SCR) for both knowledge elicitation and representation of pedagogic flows with an ontological networks approach to allow the efficient sharing and updating of pedagogic content knowledge. Finally the Pedagogic Unit (PU) schema and Pedagogic Material (PM) generation and flow control support have been studied and formalised to derive a TSL for combining pedagogic units at various levels and controlling their dynamic execution. This deliverable has thus provided an innovative framework for pedagogic flow generation and control at plan time, execution time and repair time. The framework is to have its MaestrOnto-SCR ontological network populated with actual music pedagogic knowledge and PCKs for the specific designated i-Maestro Demonstrators so that the it can be evaluated and evolved to realise its potential to make a substantial contribution to the field of e-learning in general and music pedagogy in particular.

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# 13. APPENDIX: XML Code for I-MAESTRO PU Schema

The XML code for the I-Maestro PU Schema is as follows:

```
<?xml version="1.0" encoding="UTF-8"?>
<!-- edited with XMLSpy v2006 rel. 3 sp2 (http://www.altova.com) by Ben Gardiner-Jones (University of Reading) -->
<xs:schema xmlns:xs="http://www.w3.org/2001/XMLSchema" elementFormDefault="qualified" attributeFormDefault="unqualified">
	<xs:simpleType name="PUIDType">
		<xs:restriction base="xs:string"/>
	</xs:simpleType>
	<xs:element name="PU">
		<xs:annotation>
			<xs:documentation>The Root Element</xs:documentation>
		</xs:annotation>
		<xs:complexType>
			<xs:sequence>
				<xs:element name="Metadata">
					<xs:complexType>
						<xs:sequence>
							<xs:element name="PUID" type="PUIDType"/>
							<xs:element name="Title" type="xs:string"/>
							<xs:element name="Keywords" type="xs:string"/>
							<xs:element name="PObjectives" maxOccurs="unbounded">
								<xs:complexType>
									<xs:sequence>
										<xs:element name="Type"/>
										<xs:element name="Scope">
											<xs:complexType>
												<xs:choice>
	<xs:element name="Beginner" type="xs:boolean"/>
	<xs:element name="Intermediate" type="xs:boolean"/>
	<xs:element name="Advanced" type="xs:boolean"/>
												</xs:choice>
											</xs:complexType>
										</xs:element>
										<xs:element name="Description"/>
										<xs:element name="MandatoryPrecursor" type="PUIDType" minOccurs="0" maxOccurs="unbounded"/>
										<xs:element name="DesirablePrecursor" type="PUIDType" minOccurs="0" maxOccurs="unbounded"/>
										<xs:element name="UndesirablePrecursor" type="PUIDType" minOccurs="0" maxOccurs="unbounded"/>
										<xs:element name="Contra-indicated" type="PUIDType" minOccurs="0" maxOccurs="unbounded"/>
										<xs:element name="Range">
											<xs:complexType>
												<xs:choice>
	<xs:element name="SingleShot" type="xs:boolean"/>
	<xs:element name="MultiShot" type="xs:boolean"/>
	<xs:element name="Continuous" type="xs:boolean"/>
```

```
                                                </xs:choice>
                                            </xs:complexType>
                                        </xs:element>
                                    </xs:sequence>
                                    <xs:attribute name="ID" type="xs:ID"/>
                                </xs:complexType>
                            </xs:element>
                            <xs:element name="DeliveryContext" type="xs:string"/>
                            <xs:element name="MatchCriteria">
                                <xs:complexType>
                                    <xs:sequence
maxOccurs="unbounded">
                                        <xs:element
name="ContextRef" type="xs:string"/>
                                        <xs:element name="Value"
type="xs:string"/>
                                    </xs:sequence>
                                </xs:complexType>
                            </xs:element>
                        </xs:sequence>
                    </xs:complexType>
                </xs:element>
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                        <xs:sequence>
                            <xs:element name="KnowledgeUnit"
type="knowledgeUnitType" maxOccurs="unbounded"/>
                            <xs:element name="ExcerciseUnit"
type="exerciseUnitType" maxOccurs="unbounded"/>
                            <xs:element name="PedagogicResource"
type="pedagogicResourceType" maxOccurs="unbounded"/>
                        </xs:sequence>
                    </xs:complexType>
                </xs:element>
                <xs:element name="Methods" type="methodType"/>
                <xs:element name="Roles" type="roleType"/>
                <xs:element name="Evaluation" type="evaluationType" minOccurs="0"/>
                <xs:element name="MetaScaffolding_PCK" type="scaffloding Type"/>
            </xs:sequence>
        </xs:complexType>
    </xs:element>
    <xs:complexType name="knowledgeUnitType">
        <xs:sequence>
            <xs:element name="Conditions" type="conditionType"/>
            <xs:element name="Communications" type="communicationType"/>
        </xs:sequence>
        <xs:attribute name="ID"/>
    </xs:complexType>
    <xs:complexType name="exerciseUnitType">
        <xs:sequence>
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            <xs:element name="Communications" type="communicationType"/>
        </xs:sequence>
        <xs:attribute name="ID" type="xs:ID"/>
        <xs:attribute name="Type" type="xs:string"/>
        <xs:attribute name="Description" type="xs:string"/>
    </xs:complexType>
    <xs:complexType name="conditionType">
        <xs:sequence>
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            <xs:element name="Inputs" minOccurs="0" maxOccurs="unbounded">
```

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                                    <xs:attribute name="ID" type="xs:ID"/>
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                                <xs:element name="Dynamic" type="xs:boolean"/>
                            </xs:choice>
                            <xs:attribute name="ID" type="xs:ID"/>
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                    </xs:element>
                    <xs:element name="Other" type="xs:string" minOccurs="0"/>
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            </xs:complexType>
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                <xs:sequence>
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                            <xs:simpleContent>
                                <xs:extension base="xs:string">
                                    <xs:attribute name="ID" type="xs:ID"/>
                                </xs:extension>
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                        </xs:complexType>
                    </xs:element>
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                            <xs:simpleContent>
                                <xs:extension base="xs:string">
                                    <xs:attribute name="ID" type="xs:ID"/>
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                    </xs:element>
                    <xs:element name="KGA" maxOccurs="unbounded">
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                            <xs:simpleContent>
                                <xs:extension base="xs:string">
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                            </xs:simpleContent>
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                    </xs:element>
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            </xs:complexType>
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			<xs:element name="PContentObject" minOccurs="0">
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					<xs:sequence>
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						<xs:element name="Metadata" type="xs:string" minOccurs="0"/>
						<xs:element name="LocationURI" type="xs:anyURI" minOccurs="0"/>
					</xs:sequence>
					<xs:attribute name="Type" type="xs:string"/>
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			</xs:element>
			<xs:element name="PCommunicationObject" minOccurs="0">
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					<xs:sequence>
						<xs:element name="PUID_PR_COM" type="xs:ID" minOccurs="0"/>
						<xs:element name="Metadata" type="xs:string" minOccurs="0"/>
						<xs:element name="LocationURI" type="xs:anyURI" minOccurs="0"/>
					</xs:sequence>
					<xs:attribute name="Type" type="xs:string"/>
				</xs:complexType>
			</xs:element>
			<xs:element name="PToolObject" minOccurs="0">
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					<xs:sequence>
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						<xs:element name="Metadata" type="xs:string" minOccurs="0"/>
						<xs:element name="LocationURI" type="xs:anyURI" minOccurs="0"/>
					</xs:sequence>
					<xs:attribute name="Type" type="xs:string"/>
				</xs:complexType>
			</xs:element>
		</xs:sequence>
		<xs:attribute name="ID" type="xs:ID"/>
	</xs:complexType>
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		<xs:sequence>
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		</xs:sequence>
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		<xs:attribute name="Title" type="xs:string"/>
		<xs:attribute name="Description" type="xs:string"/>
	</xs:complexType>
	<xs:complexType name="pflowType">
		<xs:sequence>
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						<xs:choice>
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								<xs:complexType>
									<xs:choice>
```

```
                                                        <xs:element name="Iterative"
type="xs:boolean"/>
                                                        <xs:element name="Recursive"
type="xs:boolean"/>
                                                        <xs:element name="ReEntrant"
type="xs:boolean"/>
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                                            <xs:element name="GrassHopper" type="xs:boolean"/>
                                            <xs:element name="ButterFly" type="xs:boolean"/>
                                            <xs:element name="InterLeaved" type="xs:boolean"/>
                                            <xs:element name="Overlapped" type="xs:boolean"/>
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maxOccurs="unbounded"/>
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maxOccurs="unbounded"/>
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                            </xs:element>
                        </xs:sequence>
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                    </xs:complexType>
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                        <xs:sequence>
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                                    <xs:sequence>
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maxOccurs="unbounded"/>
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                        </xs:complexType>
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                                            <xs:element name="fullyMediated"
type="xs:boolean"/>
                                            <xs:element name="unmediated"
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                                <xs:element name="WeaklyCoupled" type="PUIDType"
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                                <xs:element name="ill_Coupled" type="PUIDType"
minOccurs="0" maxOccurs="unbounded"/>
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                </xs:sequence>
```

```
	</xs:complexType>
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			<xs:element name="Description" type="xs:string"/>
		</xs:sequence>
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</xs:schema>
```


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