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THE KNOWLEDGE MANIFOLD

AN EDUCATIONAL ARCHITECTURE THAT SUPPORTS INQUIRY-BASED CUSTOMIZABLE FORMS OF E-LEARNING

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ABSTRACT

This paper discusses the ongoing educational paradigm shift and introduces the concept of a *Knowledge Manifold*, which is a learner-centric, open educational architecture that supports conceptual navigation and interactive exploration of an interdisciplinary knowledge landscape from the perspective of inquriy-based learning. The KM architecture is presented in the form of a number of *educational design patterns* that encode the structure of the correponding parts of the learning environment. A knowledge manifold is described as a kind of patchwork consisting of a number of linked *knowledge patches*, each maintained by a *knowledge gardener*. A knowledge patch is constructed from *context maps*, whose concepts are filled with *knowledge components*, which are designed with the overall aim to separate content from context by making use of *multiple narration* techniques. Basing the methodology on questions, seven different *knowledge roles* are introduced. The *knowledge cartographer* constructs context maps, the *knowledge librarian* fills the maps with content, the *knowledge composer* combines the content into customised learning modules, the *knowledge coach* cultivates questions, the *knowledge preacher* provides answers, the *knowledge plumber* routes questions and the *knowledge mentor* provides a role model and supports learner self-reflection.

KEYWORDS

Knowledge manifold, educational design pattern, knowledge-pulling, knowledge patch, knowledge gardener, context map, knowledge component, multiple narration, question-based learning.

1. INTRODUCTION

Today most nations acknowledge that there is something fundamentally wrong with their school systems [28], [29]. In almost every democratic country this opinion has ventured to the forefront. During the dawning of the information age, at a time when education is globally recognized as the most important strategic investment in the future, an increasing number of young people are failing to absorb the "required knowledge" in the form presented by the school systems. The performance problems seem to be related to lack of learner motivation [4], and they seem to appear on all levels of the educational system, although they are most clearly visible in the later parts of the compulsory layers.

The traditional educational systems are structured as layered, closed architectures based on curricular-oriented knowledge-pushing. The lack of connectivity, both within and between the educational layers makes it hard for teachers to handle questions that they cannot answer themselves. This reinforces the traditional knowledge-filtering role of the teacher. "My pupils should learn what I already know - and nothing else" is a common behavior pattern at work here[1].

This paper presents an open educational architecture called a *Knowledge Manifold* (KM), which is based on interest-oriented knowledge-pulling, and which is designed in order to support inquiry-based and customizable forms of networked learning. The KM architecture is based on the following fundamental principles:

- Nobody can teach you anything. A good teacher can inspire you to learn.
- Your learning motivation is based on the experience of subject excitement and faith in your learning capacity from live teachers.
- Your learning is enhanced by taking control of your own learning process.
- No 'problematic' questions can be answered in an automated way. In fact, it is precisely when your questions break the pre-programmed structure that the deeper part of your learning process begins.
- Respect for ignorance, which is of fundamental importance in a non-elitist knowledge society, can only be upheld when the ignorant person is uneducated[2].

An educational architecture consists of a number of educational design patterns [1] that encode the structure of the corresponding learning environments. This paper advocates a paradigm shift away from the traditional teacher-centric, knowledge-pushing pattern, called *Tenured-Preaching/Learner-Duties*, towards a learner-centric, knowledge-pulling pattern, called *Requested-Preaching/Learner-Rights*. It also introduces a technique called *Question-Based Learning*, which focuses on cultivating and refining the questions of the learners in order to support them in taking control of their own learning process.

A Knowledge Manifold has the following major characteristics:

- Its design reflects a strong effort to comply with emerging international IT standards [5].
- It can be regarded as a *knowledge patchwork*, with a number of *linked knowledge patches*, each with its own *knowledge gardener*.

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[1] The need to support contact between the different layers of the educational system is widely recognized and was specially addressed in [28].

[2] The term 'educated' is being used here in the formal sense, meaning "graduated from an educational system".

- It gives the learners the opportunity to ask questions and search for *live, certified knowledge sources* to discuss them with.
- It has access to distributed archives of *resource components*, which are described using standardized metadata annotations [22].
- It allows teachers to construct customized learning modules by *composing resource components*.
- It makes use of *conceptual modeling* in order to construct context maps whose concepts (and concept relations) are filled with content. This supports the separation of content from context and promotes the reuse of content across different contexts.
- It contains a *concept browser*[3], which is a new type of knowledge management tool that lets the user navigate the context maps and view the content under a dynamically configurable set of aspects.

2. THE ONGOING EDUCATIONAL PARADIGM SHIFT

2.1. The educational crisis - the carrot rape

During the "good old times" the schools were run on a mixture of the carrot and the whip - leaning heavily towards the latter. Such traditional schools often took on the form of a mental torture- and humiliation-arena, that was brought down upon you as soon as you were caught not having done your homework and not knowing your answers. Although utterly unpleasant, it is important to realize that this kind of negative motivation is a highly efficient driving force for rote learning. It is no coincidence that the traditional school systems seem to work best in cultures where negative motivation is still effective.

While they are still compulsory, the democratic school systems of today have abandoned the whip as a pedagogical tool. This has been a necessary consequence of the victories of the human-rights movement as applied to children, the inevitable outcome of the school democratization process. Since the evolutionary disappearance of the whip, the school-reforms have all been aimed at "polishing up the carrots" in various ways - in order to make them more palatable to the "educational customers". The problem with this outlook is that many customers are not directly driven by their desire to consume, to put it mildly, but rather by their desire to endure - endure an endless torture of uninteresting and repetitious activities that they didn't ask for in the first place. And on top of that, as a pupil you have to put up with people that are paid to pretend that it is all fun and interesting - and seldom dare to confront the fact that they are responsible for confining you, since your presence is required by law.

This is a bit like being force-fed with carrots, which is why we can refer to this educational design pattern as the *carrot rape*. An increasing number of young people are reacting to it by abandoning their learning projects - "losing their interest" as the term goes - often finding refuge in the willingly awaiting arms of the popular music industry.

The carrot rape has played a decisive role in producing a lost generation of knowledge seekers. Today, instead of devoting themselves to strengthening their

[3] Concept browsers are described in [8] and [10]. A first prototype of a concept browser, called *Conzilla* [17] has been developed over the past three years by the KMR group at CID [16]. Using Conzilla, several instances of knowledge manifolds are presently under construction at CID, e.g. within the fields of mathematics [9], IT-standardization and interoperability between different systems for e-commerce [25].

mental faculties, thousands upon thousands of young minds are dedicated to various aspects of the "Brick-in-the-Wall philosophy" so adequately expressed by Pink Floyd: *We don't need no education - we don't need no thought control*! [27].

2.2. Tenured-Preacher/Learner-Duties: the traditional educational pattern

Figure 1 shows the traditional educational design pattern of life-long teaching and compulsory learning[4], which is still practiced within the basic layers of most school systems. The teacher is seen as a tenured (= securely employed) preacher, who can teach as he or she wishes, without having to worry about whether the learners like it or not - at least not as long as their signs of dislike can be kept within socially controllable bounds. This behavior pattern is referred to as "agent 007 with a right to kill interest". It reinforces the employment-security attitude that is inherent in the tenure-based pattern. In this context, getting a permanent staff position (getting your tenure) is considered to be the main measure of teaching qualification.

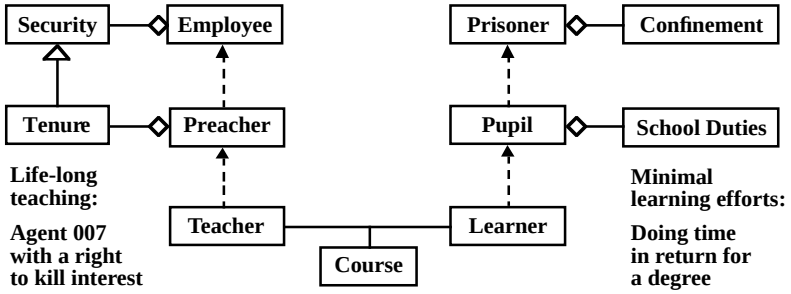

Figure 1. The Tenured-Preacher/ Learner-Duties educational design pattern.

The learners are seen as pupils with a number of school duties, which make them prisoners of a compulsory detention system[5]. Therefore they tend to adopt a strategy of minimal learning efforts - "doing time in return for a degree".

The Tenured-Preacher/Learner-Duties pattern is often accompanied by excessive testing. Although most tests tend to favor pure memorization strategies (learning by imitation), the negative motivation associated with not passing the test may in fact be one of the major advantages of knowledge-pushing (as opposed to knowledge-pulling) educational systems. As a learner, you sometimes need a push to get you through the boring parts of your journey towards knowledge and understanding. How to supply such pushes is a major problem that is associated with any purely interest-driven educational system. Intelligent mentoring, in the form of positive expectations supplied by accepted role models, is probably an effective strategy to be applied here.

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[4] The patterns in this article are expressed in ULM (Unified Language Modeling), which is modeling technique developed by the author [7], [8] based on UML [15]. The dashed arrow is read "*is a*", (**Teacher** *is a* **Preacher**), the diamond-head arrow is read "*part of*", or "*has*" in the opposite direction, (**Preacher** *has* **Tenure**) and the triangle-head arrow is read "*kind of*" (**Tenure** *kind of* **Security**). For a brief overview of ULM, see [10].

[5] **Learner** *is a* **Pupil** *has* **School-Duties**, **Pupil** *is a* **Prisoner** *has* **Confinement**.

2.3. Maintaining respect for ignorance in a knowledge-pushing society

As stated above, maintaining respect for ignorance is of fundamental importance in a non-elitist knowledge society. However, this becomes problematic in societies that implement knowledge-pushing school systems, where everyone is forced to become educated. A generation ago, an ignorant person was (most probably) uneducated and therefore had a perfectly good reason for being ignorant - a reason that made it possible for him to preserve his self-respect. Today our schools turn out far too many educated but ignorant persons, who know that they have failed miserably and therefore have a weakened (internal) respect for themselves. Hence they often become obsessed with obtaining "external respect" from others.

2.4. Requested-Preacher/Learner-Rights: an emerging educational pattern

Figure 2 depicts the emerging educational design pattern that characterizes much of the present course development for industry, as well as the many-fold activities of various kinds of study-circles. The teaching is not life-long, but rather performed on request. The teacher is seen as a pedagogical knowledge resource as well as a pedagogical consultant. When somebody is interested to learn, then it is the proper time to teach. "You teach as long as somebody is learning" is the behavior pattern at work here.

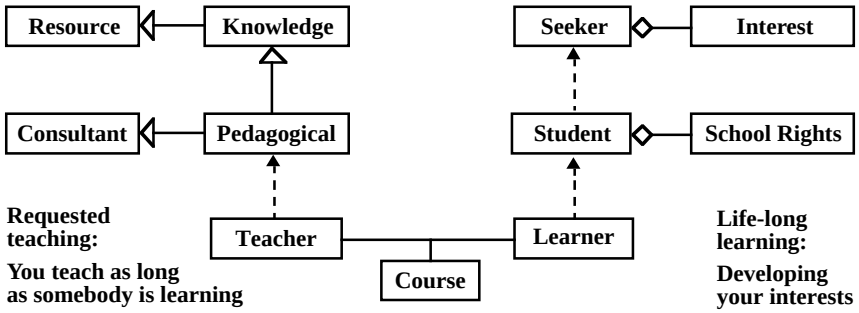

Figure 2. The Teacher-Resource / Learner-Rights educational design pattern

On the complementary side of this pattern, the learners are seen as students with a number of school rights - knowledge seekers basing their life-long learning on interest.

A common reaction to any form of knowledge-pulling educational design pattern is to question its effectiveness in supporting weak students. Regarding this issue, I have taken the liberty to include the following passage from [4], written a decade ago by Jack Douglas[6].

> Educationalists […] generally insist that self-education, mutual self-help, tutorials, and other forms of informal education are all fine for the brightest and most creative, but that they are totally unavailable or useless for the ordinary (mean or least-common-denominator) students. That is the opposite of the truth. All of our schools at all levels and in all communitites are pervaded by a vast plethora of informal, local, individualized learning groups studying and teaching themselves and each other how to repair motorcycles and cars, how to build radios or computers, how to surf every good surfing area in the world, how to dive in the ocean or soar in the sky, and how to do millions of other things. […].

[6] Professor of sociology at the University of California at San Diego.

The obvious fact is that the education bureaucracies are far more destructive of the motivation and learning of the less symbolic students than of the symbolically brightest students. The bureaucratic teachers do not understand them or sympathize with them because they rely far more on direct learning by observing and doing and by word of mouth than on the textbooks the teachers use. […].

Bureaucratic education has had little negative effect on the symbolically brightest and most creative. People like the late Richard Feynman still manage to survive the formal processing of their minds, largely by tuning out and going their own ways in spite of the bureaucratic tentacles. But the ever greater bureaucratization of education at all levels has had a devastating effect on the less symbolic and more least-common-denominator students. As the bureaucracy has grown, those students have come more and more to loathe the schools and almost any form of text-based learning associated with the schools. Science has been the worst victim of this trend because the students are first introduced to science in the schools by the rote methods of bureaucracy and because creative science demands more freedom, more curiosity, more individualized learning, and more contrarianism than most other realms of knowledge. […].

There is a direct and remarkably high correlation between the growth of the educational bureaucracies and the growth of rage and rebellion against education on the part of less-symbolic students. The bureaucratization came first and directly caused the rage. Now some of our schools, trying to educate such alienated students, are literally being patrolled by police, but even they cannot stem the tide of revolution. Teachers dream of returning to the good old days of Blackboard Jungle, way back in the 1940s and 1950s when schools were neighborly and informal and before students hit, raped and murdered teachers. In view of what has been happening in the centrally planned, bureaucratic states around the world, is this really so surprising?

3. THE KNOWLEDGE MANIFOLD EDUCATIONAL ARCHITECTURE

A Knowledge Manifold consists of linked *Knowledge Patches* - each maintained by a custodian called a *Knowledge Gardener*. A KP in turn consists of a set of learning resources[7] that are tied together with maps that represent the subject domain context model of the KG. Such context maps are preferably constructed using ULM, since the resulting context maps have clearly defined and verbally coherent visual semantics. This makes it easy to cognitively integrate the conceptual relations and achieve an overview of the context. Moreover, making the context visually explicit provides important support for the conceptual calibration activities that form an integral part of the learning process

The structure of a Knowledge Manifold is modeled on the mathematical concept of *manifold* [2]. A mathematical manifold consists of a set of base-points, each with a number of local descriptions (= coordinate maps) of its topological neighborhoods. These descriptions are calibrated into a coherent whole through a so-called atlas, which describes how the maps are related to each other**.** In a KM, a base-point corresponds to a concept, and the coordinate maps of the base-point neighborhoods correspond to the context maps (knowledge patches) containing the concept and representing its contextual neighborhoods[8].

[7] In KM terminology, we use the term *knowledge component*, when we assume the perspective of the teacher(s), the term *information component* when we assume the perspective of the learner(s), and the term *resource component* when want to remain neutral in this respect. It is the *transformation* of learner information into learner knowledge, and eventually the *transmutation* of learner knowledge into learner understanding, that is the overall aim of the learning process.

[8] For a discussion of the *contextual topology* induced on a Knowledge Manifold, see [10].

3.1. The distributed Knowledge Wherehouse

When you are designing a course, you try to connect the content with the context, identifying the target group, the prerequisite knowledge, the presentation schedule, etc. In contrast, when you are designing a resource component, in order to support its reusability across different contexts, you try to *separate* the content from the context. This fundamental difference is discussed in detail in [7] and [8]. The aim is to create parallel descriptions of the content from many different angles at many different scales of resolution[9] (= levels of difficulty). The modern hyper-text techniques then make it possible for the learners to choose which angle and which resolution of the story that they want to interact with - just like a computer game, which offers individually adjustable preferences and skill-levels of interaction.

A well designed resource component can be likened to a skiing area, with several different slopes down the same mountain - each one with its own annotated level of difficulty, and marked off by a color code which constitutes the internationally standardized metadata classification scheme for skiing slopes. Nothing prevents a skier with green "skiing knowledge" to choose a red or a black slope, but the skier knows pretty well what to expect in such a case.

In a KM, each concept serves as an entrance into a distributed archive of resource components that are related to it in some way. Moreover, these components are described with metadata in accordance with emerging international standards[10]. In this way, a context map works as a non-linear (contextual) index into the archived components that can be searched, accessed, downloaded and combined in order to create customized learning modules.

3.2. Edutella - a context-based search service for the Semantic Web

The W3C[11] has created an initiative called the *Semantic Web* [26], which embodies the vision of the next generation of the Internet. The technical basis for the Semantic Web is a metadata language called RDF [23], which makes it possible for anyone to "state anything about anything" in a way that is machine-understandable[12].

The knowledge management research group at CID is participating in an international project called PADLR[13], supported by WGLN[14]. The driving vision of this project is a distributed learning web infrastructure, which will make it possible to exchange/annotate/organize and personalize/navigate/use/reuse modular learning resources, supporting a variety of courses, disciplines and universities.

The RDF-based web will allow much more advanced forms of search tools than the HTML-based web of today. Within the PADLR project, we are collaborating with research groups at Uppsala, Stanford, Hannover and Karlsruhe, in the creation of Edutella [3], and infrastructure which includes a search service for a peer-to-peer network that can exchange educational metadata retrieved by context-based searching across the Semantic Web.

One of our research visions is what we call the *Conceptual Web* [11]. It will live on top of the semantic web and contribute to making the latter accessible to humans in a more appealing and understandable way. This will be especially important in order to support effective e-learning in the emerging semantic age[15].

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[9] The technique for achieving this is termed *multiple narration* and is described in detail in [8].
[10] such as IMS-IEEE/LOM [22] with an RDF binding [13], [23].
[11] World Wide Web Consortium.
[12] i.e. has machine-readable semantics.
[13] Personalized Access to Distributed Learning Resources [21].
[14] Wallenberg Global Learning Network [20].
[15] See [12] for a discussion of different architectural issuses involved related to this problem.

3.3. Building customised learning modules by composing resource components

A KM also contains various tools that support conceptual browsing and knowledge patch construction and editing. Using these tools, teachers and learners can construct their own knowledge patches and tailor their own learning modules (= combinations of learning resources).

Virtual Workspace Environment [18] is a distributed Learning Management System which is designed to support such component composition[16]. It is implemented using Enterprise Java technology, which makes it a scalable platform for building interactive knowledge patches. VWE makes extensive use of open standards in order to enhance integration with other systems. As is the case with Conzilla, the source code for VWE is released as Open Source.

As a learner, you are invited to browse the knowledge patches and by the help of various forms of mentoring and tutoring you are aided in the formulation of your own learning strategy and learning action plan. When you are ready, you can follow your own learning path through the material - at your own individual pace - and eventually document your learning experiences encountered along this path, e.g. by making use of your own personal portfolio[17].

An important benefit of the portfolio approach is the fact that it is difficult to compare different learning experiences. The learners should be encouraged to feel that since they have taken unique paths through the knowledge landscape, they all have something unique to offer in terms of documented experiences and impressions. In this respect, everyone is therefore "the best". Frank Sinatra's famous song "I did it my way!" is the educational design pattern that should be applied here.

3.4. Live discussion service - man to man via machine

It is a fundamental assumption of the KM architecture that automated presentation systems can raise questions but not give answers in any deeper sense. As stated above, it is precisely when the questions break the framework of the pre-structured presentations that the non-trivial part of the learning process begins. When a learner gets stuck with a question, he or she must therefore be given a chance to discuss it with living persons that have knowledge within the relevant fields of interest.

Hence, an important part of the KM architecture is an online *live discussion service* that enables learners to get in personal contact with certified resource persons (knowledge sources) that have knowledge that matches the problem domain and have declared their willingness to communicate it[18]. Instead of discussing teacher-generated questions of a general nature in front of learners that happen to be physically close - but often mentally distant - a teacher should be able to work online and discuss learner-generated questions concerning his or her special interests - questions that come from learners all over the world.

In the learning environments of the future it will be crucial to support and enhance the interest of the learners in every possible way. It is important to realize that in order to optimally support the learning process there is simply no efficient substitute for physical interaction between learners and live and inspiring teachers. The problem is that such teachers are far too few to cover the rapidly increasing

[16] VWE has been developed under the coordination of Fredrik Paulsson of the KMR group at CID and the Swedish National Agency for Education. He is also chair of the Swedish subcommittee of the ISO/IEC standardization body for e-learning technology, ISO/IEC JTC1 SC36 [24].

[17] The KMR group at CID, in collaboration with Uppsala Learning Lab [19], have developed a special portfolio system for this task.

[18] Such a system is presently under construction at CID. An interesting experiment in this direction, making use of advanced technology for presence production, is described in [6]

needs. Therefore, although it's the "next best thing", we can make use of cyberspace in order to spread quality explanations on request and create a much better match between teacher knowledge and learner interest than what we are achieving today.

The closed layered structure of the traditional educational systems, especially the lack of contact between universities and schools, is a major problem identified in [28]. The online discussion service makes the KM architecture truly open in terms of educational layers. A learner from elementary- secondary- or high school could easily get in touch with a lecturer at a university in order to discuss a problem that has eluded a meaningful discussion within the other layers.

3.5. Turning the traditional educational systems inside out

There are at least three important reasons why the discussion service system should include learners at all stages of their learning process as knowledge sources. First, in order to enhance their learning, it is crucial to engage the learners in the explanation process. It is only when you get a chance to explain something to someone else that you realize that you may not understand it as well as you thought.

Second, when you have just understood something, you tend to be very effective in communicating it. You are excited about your new insights, while at the same time you still remember what it was like not to be so enlightened. Being in this transient state of excitement over your new knowledge combined with appreciation of the reasons for your previous ignorance, gives you the potential to be extremely efficient as a teacher.

Third, a learner is often ashamed to put a question to a highly qualified knowledge source because of fear that the question might be perceived as stupid. Talking to another learner who is basically "on the same level" is often much less threatening in this respect.

Today, as exemplified on the web, anyone can say anything about anything. Hence the certification of knowledge sources becomes extremely important. Whether you are online with a professor or a fellow student, you should always know who you are communicating with[19].

A huge problem in the traditional educational systems is the lack of visible reward structures for quality teaching. The appreciation of the students is often the only form of reward that a great teacher can expect. In the discussion service system presently being constructed by the KMR group at CID, the knowledge sources will be rated by the learners with respect to their quality of service, and these ratings will be available online. This will create an "evolutionary pressure" that can be expected to increase teaching quality and benefit effective teachers, e.g. in terms of motivating an increase of their salaries.

4. QUESTION-BASED LEARNING

There are a great variety of different pedagogical approaches that emphasize various aspects of the educational process. Although *Lecture Based Learning* (by imitation) still seems to hold a dominating position in many quarters, pedagogical alternatives such as *Problem* (or *Project*) *Based Learning* are being increasingly applied. See [14] for a good overview of different pedagogical learning strategies.

A problem with PBL is that it is often the teachers that formulate the problems or the projects. This decreases the motivation of the learners in general, and stifles

[19] We are planning to use electronic signatures in order to achieve such certification.

the more creative among them [4]. It also leads to tension because of differences between what the teachers want and what the learners deliver.

Starting from the questions of the learners leads to an educational design pattern that is nataurally termed *Question Based Learning* [7], [8]. In QBL, the learners make use of conceptual modeling in order to model their own "question spaces" and develop their own learning strategies. The learner questions are treated as "official letters" to the educational authorities, i.e. they are registered and tracked in an analogous manner.

4.1. The seven different knowledge roles

The KM architecture supports seven different knowledge roles:

- The *knowledge cartographer*, who constructs and maintains context maps.
- The *knowledge librarian*, who fills context maps with content components.
- The *knowledge composer*, who constructs customized learning modules.
- The *knowledge coach*, who cultivates questions.
- The *knowledge preacher*, who provides live answers.
- The *knowledge plumber*, who directs questions to appropriate preachers.
- The *knowledge mentor*, who is a role model and supports self-reflection.

For the reasons discussed above, it is fundamentally important that all these roles should be available to both teachers and learners. "You learn as long as you're teaching" is the pattern at work here.

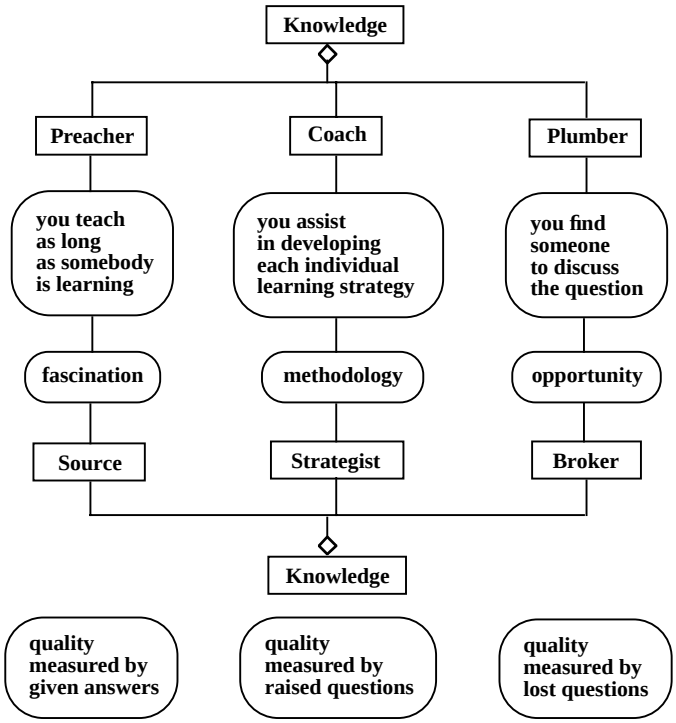

Figure 3. The Knowledge-Preacher/Coach/Plumber educational design pattern.

The first three of these knowledge roles involve construction, while the last four involve performance. Hence, in the KM architecture, there are three *constructing* and four *performing* knowledge roles[20].

The Knowledge-Preacher/Coach/Plumber pattern is depicted in Figure 3. It is coherent with the Requested-Preacher/Learner-Rights pattern of Figure 2. The knowledge-preacher is a kind of pedagogical knowledge (re)source, who is driven by fascination and evaluated on the quality of the given answers.

The knowledge coach nurtures and supports the evolving questions of the learners. This *knowledge strategist* concentrates on methodology and is evaluated on the quality of the raised questions. The knowledge coach works to enhance this quality and assists the learners in developing their own personal learning strategies for obtaining relevant answers.

When a knowledge coach is unable to answer a question, he or she proudly acknowledges this fact and transmits the question to the available network of knowledge-preachers. If this still doesn't lead to a satisfying answer, the knowledge-plumber takes over and works to establish a meaningful contact with some other knowledge-preacher - thereby ensuring a forum for discussion that prevents the question from getting lost. Hence the knowledge-plumber creates opportunity for learning, and can therefore also be described as a *knowledge broker*. The performance quality of a knowledge-plumber is measured in terms of the number and the quality of lost questions.

In summary, the knowledge-coach tries to encourage the formulation of fruitful questions, the knowledge-plumber tries to makes sure that as few of them as possible are lost, and the knowledge-preacher tries to answer them in a way that stimulates further studies of the concepts involved.

The same physical person can perform several (or even all) of these knowledge roles. However, as discussed earlier, considering the rapidly increasing demands that are being made for more education, most probably there will not be enough of such 'super-teachers' that can be present in the physical environment of the learners. The live discussion service system of the KM architecture offers the possibility of distributing these knowledge roles across physical space, and make use of cyberspace as an electronic switchboard that can achieve an effective match between learner interest and teacher knowledge and communicative ability. This will provide support for teachers that want to transform their present role as knowledge filters ("you should learn what I know") and assume the role of knowledge coach ("I will help you find out what you want to know").

4.2. Developing your own Learning Strategy

A decisive advantage of QBL is that it contributes to giving learners more control over their own learning process. Focusing on the questions of the individual learners and treating these questions with the respect they deserve, helps to foster a personalized relationship to learning that counteracts the default mode of the formalized learning process which is "learning by imitation".

This does not mean that the learners are left to themselves during the process of question formulation. On the contrary, the learners are constantly being stimulated by listening to and discussing with the teachers in a multitude of different ways. This process works to establish a sort of *Knowledge Smorgasbord*. As a learner you are exposed to a multitude of different ideas, but it is your own interest that governs your choices, and your own personal set of questions that are focused and refined.

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[20] The three constructing knowledge roles are involved in building and maintaining knowledge patches. Hence they combine into what we have called a *knowledge gardener*.

Developing your own learning-strategy involves coming up with answers to three important questions, namely "what am I interested in?", "what is there to know about it?", and "how much energy am I prepared to invest in getting to know about it?". Naturally, the answers to these questions are interconnected and mutually dependent in various highly complex ways. This development process is subject to regular iterations, which serve to modify and update the learning strategy.

5. CONCLUSIONS

A limited form of the KM architecture has been implemented within a project called the *Garden of Knowledge* [7], which was carried out at CID between 1996 and 1998. The resulting CD-rom prototype focused on the concept of symmetry in order to illuminate and explain some of the structural connections between mathematics and music[21]. In spite of its limitations, the GoK has proved effective in raising interdisciplinary interest among students of mathematics and music, as well as among the public in general[22].

No educational achitecture can be suitable for everyone. The KM architecture is designed in order to support interest-based knowledge-pulling in a networked environment. It should be seen as an alternative and not as a panacea that solves every educational problem. Moreover, adapting it as the default mode of education requires changes in the surrounding society that are beyond the scope of discussion in this article[23].

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