Multicultural Computer Science Education

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Abstract: The last few decades have seen considerable efforts on the part of scholars and policy makers to embark on initiatives to acknowledge, accept, and value cultural diversity. Education shall promote understanding, tolerance and friendship among nations and ethnic groups, and all forms of artistic expression are tools in intercultural education. Effective multicultural education means that cultural pluralism permeates all dimensions (including the curriculums in all subjects at all levels) of the educational process. This is an especially challenging issue for science educators. This paper particularly focuses on multicultural content integration in computer science (CS) education through art-based pedagogical tools. Firstly, the theoretical basis for artistically enhanced multicultural CS education is analyzed: How arts can promote: multicultural education, effective multisensory/ hybrid/ blending/ multimedia education, science education. Secondly, a technologically enhanced multicultural-art-based method is presented that promotes both CS education and appreciation for cultural diversity in Transylvania, Romania.

1. Introduction

The last few decades have seen considerable efforts on the part of scholars and policy makers to embark on initiatives to acknowledge, accept, and value cultural diversity in place of the accustomed melting pot approach whose objectives have been to assimilate minorities into the mainstream at the expense of their cultural identities. Amaram [1] identifies three organizational dynamics that contribute to the growth of the diversity perspective:

- Social justice (moral, ethical and social responsibilities toward minority members of society).
- Legal obligations to eliminate racial and ethnical discrimination in education and employment.
- Globalization, with its multicultural implications, has become an indispensable factor for business organizations in strategic competitiveness.

According to a recent report of the Committee on Culture, Science and Education (C-CSE) [2], the Council of Europe Parliamentary Assembly recalls that education shall promote understanding, tolerance and friendship among nations and ethnic groups, and all forms of artistic expression are tools in intercultural education. The report stresses that society's need for the particular competences and qualities that are developed through artistic and cultural education is greater than ever. C-CSE defines cultural education as: (1) learning and practicing the arts; (2) learning through the arts (which means the use of art-based forms of teaching as a pedagogic tool in all kinds of school subjects); (3) using the arts for the promotion of cultural and social objectives like mutual respect, understanding and tolerance, appreciation of diversity, team work, creativity, etc.

Different words like ‘multicultural’ and ‘intercultural’ have been used to describe the changes that have been happening in modern society. These terms on the one hand describe a society in which different cultures live side by side, and on the other hand express the conviction that we all become more by coming in contact with and experiencing other cultures and that people of different cultures can and should be able to cooperate with each other and learn from each other. [3]

According to Banks and Banks [4] the issue of multicultural education is of paramount importance in the twenty-first century. Valdez [5] concludes that multicultural education has the potential to decrease race, ethnicity, class, and gender divisions. Gay [6] emphasizes that it is imperative that teachers learn how to recognize, honour, and incorporate the cultural characteristics of students into their teaching strategies. Although definitions of multicultural education may vary ([4], [7], [8], [9], [10], [11], [12], [13], [14]), most of multiculturalists agree that multicultural education means learning about, preparing for, and celebrating cultural diversity, and it requires changes in school programs, policies, and practices. [15]

Despite these clear directives, very little is being done to put these insights into practice [2]. Critical pedagogy theorists identify the gap between theory and practice as a major weakness of multicultural education ([16], [17]). Regarding arts, as key tools in intercultural education, data collected from 423 K-12 teachers (enrolled in professional development programs for general education teachers in United States) indicate that teachers believe the arts are important in education, but rarely use them [18].

According to Hoffman [19], multicultural projects, often, tend to concentrate on cultural celebrations at special occasions or dates, and thus are implemented at the superficial level of food, dance, and music. Multicultural education is frequently considered as an appendix to the regular curriculum. As a result, the practice of multicultural education is minimized to folklorization.

With respect to cross-curricular links between arts and other subjects Education, Audiovisual and Culture Executive Agency of the European Commission [20] reports that:

- Just over a third of European countries establish cross-curricular links between arts and other subjects at a curriculum level, either through educational objectives, or subject-specific links.
- In some cases, promoting cross-curricular links is explicitly stated as an aim/objective of the arts curriculum. (Only one country has subject links between the arts and sciences)
- In several countries (including Romania) cross-curricular links between arts and other subjects may be established at a local or school level.

Accordingly, effective multicultural education means that cultural pluralism permeates all dimensions (including the curriculums in all subjects at all levels) of the educational process. According to Gay [15], advocates of multicultural education suggest three general approaches for how it can be accomplished in school practice: (1) teaching content about cultural pluralism, (2) teaching culturally different students, and (3) using cultural pluralism to teach other academic subjects and intellectual skills. Most of multiculturalists agree that the specific content, structures, and practices employed in achieving multicultural education should differ depending on the setting. It is expedient for teachers to elaborate their own definitions of multicultural education adequate to their specific needs, rather than imposing a rigid all-embracing structure to [15]. Consequently, although effective multicultural education presupposes institutional top-

down strategies, educators should take the initiative to implement principles of multicultural education in their own courses, rather than waiting for lagging organizational solutions.

Although there are more opportunities for teachers to use ethnic and cultural content to illustrate concepts, themes, and principles in the social studies, the language arts, and in music, multicultural education also provides a perspective for maths and science. For example ethno-mathematics ([21], [22]) presents a view of mathematical thinking that incorporates the ways in which culture and mathematics are intertwined. In the sciences there is the opportunity to study environments from the perspectives of the diversity of cultural knowledge ([23], [24]). Another possibility is to use multicultural-art-based pedagogical tools in teaching-learning scientific subjects. Best methods in this category equally promote multiculturalism and science education.

This paper particularly focuses on multicultural content integration in computer science (CS) education through art-based pedagogical tools. Firstly, the theoretical basis for artistically enhanced multicultural CS education is analyzed: How arts can promote: (1) multicultural education, (2) effective multisensory/ hybrid/ blending/ multimedia education and (3) science education. Since educators are encouraged to take the initiative, a technologically enhanced multicultural-art-based method (built around an effective multimedia software-tool) is presented (as an implementational sample) that promotes both CS education (teaching-learning sorting algorithms) and appreciation for cultural diversity in Transylvania, Romania.

2. Artistically enhanced multicultural CS education

Bennett [25] distinguishes between ethnocentrism and ethnorelativism. Ethnocentric people have not internalized perspectives emanating from other cultures and tend to value their own culture above everything else. Their early training in the home and sometimes in the school creates the habits of mind that characterize them. At the opposite side, ethnorelative people appreciate cultural perspectives other than their own, and recognize that particular cultures can only be understood within a cultural context. Bennett describes a six-stage process that moves someone from ethnocentrism to ethnorelativism. Intercultural education should become a promoter of this process.

2.1. The role of arts in intercultural education

With respect to the role of arts in intercultural education the C-CSE [2] report states that:

- Art can efficiently reinforce formal education. Cultural and artistic means of education should become an important part of school curricula.
- Diversity and a multicultural environment stimulate creativity.
- Intercultural dialogue is the basis for harmonious and peaceful co-existence.
- Music, art and dance can be effective tools for intercultural education.
- Educational institutions should initiate international co-operation projects in cultural education, especially in regions with political (or ethnical) tensions.
- Art and educational institutions need to rethink their roles in connection with cultural education. A new learning culture has to be promoted by enabling new learning communities and supporting networks.

- Recent cultural monitoring studies showed that parents would like to see more art and culture in schools because they believe that cultural education plays a very important role in the comprehensive development of their children's personalities.

Oreck's [18] study reveals that awareness of student diversity and the need for improved motivation and enjoyment in learning are the dominant teacher-motivations for using the arts. Field [26] examined how arts education, and specifically music, in the International Baccalaureate Middle Years Programme promote intercultural awareness. He concludes that an international curriculum should aim for intercultural/international understanding. According to Thomas and Mulvey [27], arts promote student understandings of the values, goals, and practices of community-based work and enable meaningful student roles in community-based partnerships.

New information and communication technologies have strongly increased the possibilities for, and the impact of, cultural education, both in formal and informal education. According to Gadsden [28], the study of the arts (music, visual art, and performance, etc) in education has taken on new venues in supporting learning and teaching through technology and multimedia.

2.2. Technologically and artistically enhanced multisensory/ hybrid/ blending/ multimedia teaching-learning methods contribute to effective education

Arts (dance, music, rhythm, theatrical role-playing) promote such a multisensory learning environment that involves almost all senses: visual, auditory, kinaesthetic, and tactile. Since multisensory training protocols are closer to natural settings than the unisensory ones, they produce more effective learning. Recent research [29] has demonstrated that the human brain learns and operates optimally in environments in which information is integrated across multiple sensory modalities.

Findings in brain research have revealed that there are multisensory interactions both in the case of perceptual tasks and settings and throughout processing. Multi-sensory interactions have been identified in the early sensory, association and other cortical areas, including feed-forward and feed-back pathways ([30], [31], [32], [33], [34], [35], [36], [37]). Researchers have also localised convergent neural pathways onto multi-sensory neurons ([37]) that may provide the substrate for multi-sensory binding [38]. Typical characteristics of multisensory neurons are that they fire only when more than one sensory modality is activated ([39], [40], [41]); they are characterized by supra-additive response to the presentation of co-occurring events.

According to Hung [42], these findings in neuroscience have immediate implications for higher-level thinking skills. Stevens and Goldberg [43] conclude that our brains desire multi-sensory input and learning engages the whole body. Staley [44] emphasizes that senses do not reach only our feelings, emotions and aesthetic sense, but our intellect as well. For example, research on nonverbal communication and cognition revealed that dance can foster creative problem solving and the acquisition, reinforcement, and assessment of non-dance knowledge. [45]

Digital elements have moved artistically enhanced multisensory learning closer to other modern educational concepts like hybrid and blended learning. Hybrid education combines traditional face-to-face instruction with online technologies [46]. Most researchers agree ([47]) that hybrid courses, when designed carefully, combine the best features of in-class teaching with the best features of e-learning to promote active student learning [48]. Furthermore, since hybrid learning treats students as individuals with different learning habits, learning style and preferences, it has the potential of considering some of the various learning needs ([49], [50]).

Researchers define blending learning as (1) effective combination of different delivery-modes, teaching-models and learning-styles [51]; (2) optimal mixture of face-to-face classrooms, live e-learning, and self-paced learning [52]; (3) effective integration of various learning techniques, technologies, and delivery modalities to meet specific communication, knowledge sharing, and information needs [53]. Since artistically enhanced multi-sensory elements facilitate careful hybrid course design, and contribute to the effective combination, effective integration and optimal mixture regarding blended learning, they promote optimal hybrid/blended teaching-learning strategies.

Multimedia applications can increase students' motivation to learn, and often lead to a better understanding of the studied topics [54]. Research in multimedia educational techniques goes hand in hand with perceptual research of multi-sensory facilitation. Through realistic animations, attractive musical sound and vivid colours abstract concepts are brought to life. In order to increase their impact, some of the software-tools implement the so-called user-in-the-loop feature [55].

The effectiveness of these materials depends on whether learners have sufficient cognitive resources to perceive and process the essential information ([56], [57]). According to the dual-coding theory, greater total information can be processed when information enters the system through multiple processing channels [58]. Other findings show that multi-modal processing results in distributed cognitive load and, thus, information can more easily be chunked into short-term memory and used to build long-term representations [59]. Research in cognitive theory of multimedia learning ([60]) adds further evidence to the conclusion that the mechanisms of multi-sensory facilitation can have important benefits in pedagogy [29].

2.3. Technologically and artistically enhanced science education

According to Katai and Toth [61], science and art are a winning combination in educational contexts because: (1) it contributes to a balanced involvement of both sides (academic/artistic) of the brain in the classroom that could significantly improve the teaching-learning process; (2) it promotes various ways of learning that also enhance the educational process. Schaffer, Stern and Kim [62] suggest the science-art combination especially when concepts need to be comprehended mentally, physically and emotionally.

Experiments applying neuroimaging technologies (MEG, FMRI, PET, etc) have shown that activities involving numbers, logic, sequential tasks and in general analysis are more closely associated with the left side of the brain. Then again, activities involving music, imagination, colours, or creative expression are more active in the right hemisphere. Some research in this field revealed that a balanced involvement of both sides of the brain in the classroom could significantly improve the teaching-learning process [63].

Gardner ([64], [65]) emphasizes that a mixture of different ways of learning characterizes us, and he identified nine intelligences (musical intelligence, bodily-kinaesthetic intelligence, logical-mathematical intelligence, etc). One of the important messages of Gardner's work is that students need to learn in various ways. For example, teachers should not allow their visual or logical learners to rely only on their most comfortable intelligence.

In recent years several papers described works that combine science education with art. These initiatives can be categorised as follows:

1. Professional art performances that use science as thematic element (art dominates science). ([66], [67], [68], [69], [70])

2. Professional art productions that illustrate abstract scientific models and phenomena (balanced presence of art and science). ([62], [71])
3. Art-based methods for science education (science dominate art). ([61], [72], [73], [74], [75])

The advantage of the second category productions is that it can be exploited from both scientific and artistic perspective.

Katai and his colleagues describe three third category technologically and artistically enhanced multisensory methods for teaching-learning (1) elementary algorithms [76], (2) recursion [77] and (3) sorting strategies [61]. The didactical experiments described in these papers empirically prove the efficiency of these methods. The artistic elements integrated in the multimedia software-tools the methods are based:

1. The loop-skeletons of the elementary algorithms are codified as instrumental sound-sequences.
2. Segments from the classical piano masterpiece, Für Elise by Ludwig von Beethoven, are applied as background music for certain instruction-zones of the recursive sub-programs during their simulation processes.
3. Videotaped amateur dance performances illustrate sorting strategies.

To move the third method to the second category, Sapientia University (Romania) initiated collaboration with a professional art institution and modern-dances were replaced with multicultural Transylvanian folk-dances. Romanian, Hungarian, German and Gipsy folk-dance choreographies were designed to illustrate different sorting algorithms. The fruits of this collaboration are such art-science productions which equally promote multiculturalism and computer science education.

3. Multicultural CS education initiated by Sapientia University

Sapientia is a Hungarian University located in Transylvania (Mures county), part of Romania. Several ethnic groups coexist in this region like Romanian, Hungarian, German, Gipsy, etc. During its controversial history Transylvania was often the scene of political tensions. Consequently, promoting multicultural education is a very important issue in Transylvania. In order to promote the multicultural education of the CS subjects in schools of Mures county Sapientia University signed a collaboration protocol with the local School Inspectorate.

The aim of the ALGO-RYTHMICS: science and art without ethnic borders project is:

1. To develop a multimedia didactical DVD that integrates:
    a. Video recordings of multicultural folk-dances that illustrate sorting-algorithms;
    b. Software-tools that pave students' way from the comprehension of scientific message of dance-performances to the implementation phase of the programming process.
2. To initiate an annually organized artistic programme for the local community (students, teachers, parents, etc) that treats scientific themes from the educational syllabus. According to Tazouti, Malarde and Michea [78], modelling parents' beliefs relating to education indirectly promotes children's intellectual and academic performances.

According to the specific characteristics of the six selected algorithms the choreographies have to include the following basic element:

- Comparing two elements (all algorithms)
- Interchanging two elements (all algorithms) (see Figure 1)
- Dividing the current sequence in two sub-sequences (quick-sort and merge-sort)
- Partitioning the current sequence in two sub-sequences (quick-sort)
- Merging two neighbour sub-sequences (merge-sort)

Figure 1: Romanian folk-dance (sub-region Bihor, Transylvania). Interchanging two elements.

The algorithm-dance associations were established taking into account their common defining characteristics (insert-sort: with Romanian folk-dance, shell-sort: with Hungarian folk-dance, merge-sort: with German folk-dance, select-sort: with Gipsy folk-dance, bubble-sort: with "Csángó" folk-dance, quick-sort: with "Székely" folk-dance). The number-sequence is personified by the dancer-sequence (dancers wore the corresponding number on their dress). Consulting the choreographers, proper dance-steps were chosen for all key-operation of the algorithms. Each choreography has a dynamic intro simulating the mixing process of the numbers and ends with a vivid finale emphasizing the ordered character of the sequence. The central parts of the choreographies closely follow the corresponding sorting strategies. Balanced art-science collaboration is characterized by the followings: (1) The choreographers promote the artistic value of the dance-performances (specific dance-steps were chosen for interchanging two boys, two girls or a boy and a girl); (2) The CS teachers defend the clarity of the scientific message.

The designed didactical method can also be categorized as dynamic visualization, a special form of multimedia learning that is characterized by its interactive nature and its extensive use of visual representations of information. Effective implementations of dynamic visualization integrate design elements that direct the learner's attention to important aspects of the learning material. These accessories enhance learning because they can reduce the need for the processing of nonessential information, such as required during the search for essential

information [57]. Individuals learn more efficient when guidance is used in discovery-based learning in multimedia contexts [79]. On the other hand learners' perception of information is more effective when they can control the advance of the presentation from one segment to the next rather than viewing a continuous multimedia material ([80], [81], [82]). Segmenting should be applied in circumstances where the intrinsic load of the materials is so high that learners do not have enough cognitive resources for the essential processing of the content. A recent meta-analysis of 26 studies comparing dynamic and static visualizations conducted by Höffler and Leutner [83] showed a greater benefit of dynamic over static visualizations when the target knowledge was procedural motor knowledge rather than procedural or declarative knowledge.

Accordingly, to increase the didactical impact of the sort-dances:

- Graphical elements (applied to the video-recordings) emphasize that number-sequence is stored in an array.
- Segmenting the video-recordings the designed software-tool allows of interactive step-by-step examination of the algorithms.
- Representing the number-sequence as a black-box sequence, an interactive computer simulation program checks if students have comprehended the essence of the analyzed sorting strategy. Students are invited to recreate the operation-sequence (comparing, interchanging, dividing, partitioning, and merging) of the corresponding algorithm.

The following syllabus (the DVD can also be considered as an additional e-learning tool for self-paced learning) is suggested:

1. Students view the dance-performance that illustrates the analyzed sorting algorithm. The Teacher, as a narrator, direct students attention to important aspects of the sorting-choreographies.
2. Using the segmented version of the video-recording, students delimit and identify the key-operations of the algorithm.
3. Students are invited to reconstruct the operation-sequence. At each step students have to choose the next operation to be executed and after this they have to identify the elements the selected operation has to be applied on. For example, if the selected operation is "comparing" the software waits for two clicks on the corresponding dancers.
4. Students are invited to repeat the reconstruction process of the algorithm on a black-box sequence. The software informs them about the results of the comparing operations. (see Figure 2)
5. Teachers briefly discuss cultural aspects of the dance-performances with students.

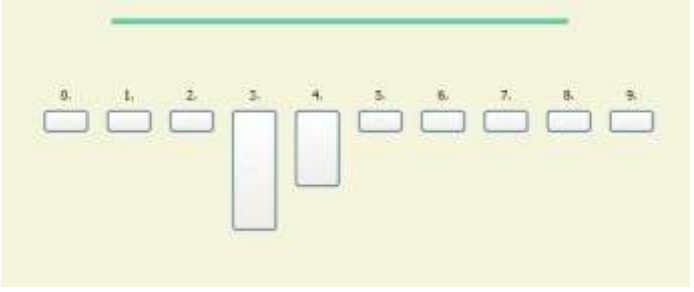

Figure 2: Multimedia software-tool. Comparing two elements.

The urge necessity of such a pedagogical effort is also motivated by the fact that, according to the common (disappointing) conclusions of several studies, beginner students at the end of their programming courses, generally speaking, cannot program, trace programs or design programs at acceptable levels, and the problem is both long-standing and has international character ([84], [85], [86]). Navrat [87] emphasizes the abstractness of the programming process as a possible factor contributing to students' difficulties in learning to program. Sciences in general often deal with concepts for which students have no real-life references and incorporate invisible factors and abstractions [88]. This root of the problem itself suggests that the efficiency of science education (particularly CS education) can be increased by multi-sensory approaches.

4. Conclusions

The presented teaching-learning strategy is built on four central concepts of the modern education: multisensory learning, multimedia education, multiculturalism and interdisciplinarity. As is referred above, recent findings in the fields like brain research, cognitive psychology and learning theories theoretically explain why such didactical methods could be more effective than traditional ones. Promoting effective multisensory/hybrid/blending/multimedia learning carefully designed technologically and artistically enhanced education improves students' learning output at all levels in all subjects. Didactical experiments empirically support the theoretical conclusions (Katai et al. 2008; Katai, 2009; Katai & Toth, 2010). Choosing artistic elements with multicultural content teachers ensure the multicultural character of their curses. Professional art performances can also be exploited on the stages to promote understanding, tolerance and friendship in racially and ethnically diverse communities.

The ALGO-RYTHMICS project illustrates how the unity-in-diversity ideal (the European Union's motto) can be implemented in educational context: Multicultural artistic performances (from a politically controversial region) promote the cause of universal science. Arts are universally considered to be an indispensable component of a well-rounded education, and they are compulsory subjects in all educational systems. The suggested method illustrates how arts can be integrated in science education at all levels (scientific content in artistic frame), and how CS classes can transmit messages like: 'No culture is the right culture' and 'There are qualities in all cultures that can be beneficial for any of us'.

According to Schaffer et al. (2001), the science-art combination is strongly recommended (among others) for the infusion of energy and excitement that can make students more receptive to learning. They observed that students, who generally are not very focused, were very engaged in lessons that integrated dance, and they enjoyed it. Additionally, combining the traditional (folk-dances) with the modern (computer sciences) and arts with sciences, the presented method fructifies the energy from the attraction of opposites.

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