Multi-sensory informatics education

Authors: Zoltan Katai, Laszlo Toth and Alpar Karoly Adorjani

Description of the achievements

Introduction

According to a recent report of the joint Informatics Europe & ACM Europe Working Group on Informatics Education, for a nation or a group of nations to compete in the race for technology innovation, the general population must understand the basics of informatics: the science behind Information Technology. To be competitive in the 21st century's job market, students must understand the key concepts of informatics. The report describes computational thinking as an important ability that all people should possess. The working group emphasizes that informatics-based concepts, abilities and skills are teachable, and must be taught, in the primary and particularly secondary school curriculum. We totally agree with this statement. (http://www.informatik.org/upload/pdf/ACMandIEreport.pdf)

In the last five years we developed multi-sensory methods [1,2,3,4] for teaching-learning some basic concepts that are included probably in every introductory informatics courses: algorithms; programming languages; abstraction; structured programming (sequence, selection, repetition); basic data structures; basic algorithms (searching, sorting, etc); recursivity; performance and complexity; parallelism; etc. More senses mean more efficient teaching-learning process because:

- more senses – more information;
- different students – different dominant senses;
- different students – different ‘‘intelligences”;
- multiple-senses – more pathways of locating the stored information;
- multiple-senses – distributed loading;
- combined senses – more efficient learning process.

Multisensory education in the digital era

Montessori initiated the multi-sensory learning movement about 90 years ago. In recent decades technology integration in education has opened up new vistas for researchers and teachers who are interested in multi-sensory teaching-learning methods. Reflecting on terms like multi-media and multi-sensory we understand that the nearly one hundred year old multi-sensory movement has entered in a new dynamic era.

Revolutionary discoveries in neuroscience and important developments in cognitive psychology have resulted in new ways of thinking about the relationship between senses and learning. It is more and more evident, that our brain is organized to elaborate information, coming from the different sensory channels, cooperatively, in order to have a complete vision of reality [5]. Some research [6] addresses multi-sensory learning neurons, specific neurons in the brain that fire only when more than one sensory modality is activated by the environment [7]. According to Hung [8] the recent findings in neuroscience have immediate implications for higher-level thinking skills (abstract problem solving, inference, deduction, and so on). As Stevens and Goldberg [9] state, two of the core principles of brain-based learning are: multi-sensory input is desired by our brains; learning engages the whole body. Researchers emphasize that senses reach not only our feelings, emotions and aesthetic sense, but our intellect as well. In the opinion of the medical neuroscientist Dave Warner the traditional forms of information representation have been "perceptually deficient", meaning that even multimedia digital content fails to consider "the extraordinary capacity of our brain to capture and process information from [all of] our senses" [10].

Increasing student motivation: a major issue for modern education

According to Prensky [11] "today's students are no longer the people our educational system was designed to teach". They should be approached as "digital natives" being more familiar and comfortable with the use of technology than with traditional lecturing methods [12,13]. Otta and Tavela [14] emphasize that "new millennium learners" [15] are not indifferent to the quality of the e-learning experience. The instructional challenge of the self-paced e-learning environment lies in keeping (generating, sustaining, not diminishing) students enthusiastic, focused, and engaged by optimally exploring the potential which lies in technology.

Constructivist theory describes motivation as a "necessary prerequisite and co-requisite for learning" [16]. Motivation is required to initiate and to catalyze the learning process until the knowledge construction has been completed [17]. Motivation theorists distinguish between intrinsic motivation (referring the internal drive; doing something because it is inherently interesting or enjoyable) and extrinsic motivation (coming from factors outside the individual; doing something because it leads to a separable outcome) [18]. Research on intrinsic motivation has revealed the outstanding role this type of motivation has in promoting high-quality learning [19,20]. It has been proved that environments that engage students in the learning process yield stronger intrinsic motivation [21,22].

Stimulating motivation is a primary goal regarding the introductory part of any e-learning or traditional lesson. Stimulating curiosity can be an efficient strategy in this sense. Curiosity is an emotional-motivational state that has a high potential to make learning intrinsically rewarding and highly pleasurable [23,24]. Providing novelty, incongruity and surprise are considered effective ways to arouse curiosity and to combat apathy [25,26].

Active involvement and moderate-progressive challenge should play key roles in sustaining students' motivation during the body of the learning unit. Research on challenge as a motivator shows that moderate challenges (balance of challenge and skills) are optimally motivating [27,28,14]. Relevant active involvement is crucial regarding intrinsic motivation, since it may have determinative influence on sustaining and maintaining students' engagement during the learning process [29,30].

The didactical methods we are going to present below try to exploit the following motivational principles:

- purposeful focus on arousing and sustaining students' motivation;
- principle of genuine active involvement;
- principle of moderate progressive challenge;
- principle of gradual shift from concrete to abstract.

Technologically enhanced multi-sensory method for teaching-learning elementary algorithms

In [1] we introduced a new multi-sensory method to improve teaching-learning of elementary algorithms. Any elementary algorithm has a ''loop skeleton", its structure of loops. Instructions representing the nucleus of the loops can be seen as the ''meat-parts" of the algorithm. We recommended the following two-step method: (1) the loop skeleton is established; (2) the skeleton is filled up with adequate instructions. We also developed a software-tool that makes it possible to create program-skeletons with different loop structures in an automatic way: (1) giving the parameters of the loop skeleton; (2) drumming the loop skeleton in (using the keyboard students drum the rhythm-pattern of certain loop skeletons). On the other hand the software plants piano sound and delay procedures in the nuclei of each loop instruction. This module functions as a loudspeaker of the loop skeletons. When the algorithm has loops in both branches of a selection, in these parallel loops we implemented the same sounds but with different musical instruments. The application makes possible the following multi-sensory learning experience: while students are listening to the loop skeleton of the algorithm (represented by its piano-sound sequence), they keep their eyes on the running program (the instruction which is being executed is highlighted). They can see, hear and feel the pulsation of the algorithms.

In order to investigate the efficiency of the presented method and software-tool we performed a didactical experiment. The results confirmed our theoretical expectations that the multi-sensory method we developed contributes to the effectiveness of the learning process and memorizing. (For more details see [1])

Technologically enhanced multi-sensory method for teaching-learning recursion

In [2] we introduced a new multi-sensory method to improve teaching-learning of recursive algorithms. The method explores in a harmonic way the visual, auditory and kinesthetic senses of students. It helps them to imagine abstract concepts and processes. Students are invited to play so called “recursive scenarios”. The method also makes use of didactical software that creates “the melody line” of the recursive procedures and functions.

In order to prove empirically the efficiency of the method we performed an experiment too. The results supported the conclusion that the multi-sensory method we proposed improves students’ skill to analyze, design and implement recursive procedures and functions. (For more details see [2])

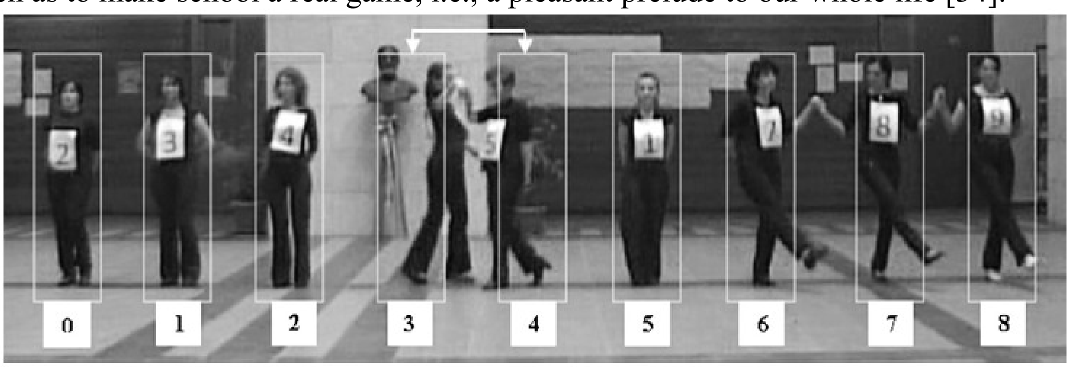
Staging a recursive scene.

Technologically and artistically enhanced multi-sensory method for teaching-learning sorting algorithms

Two main reasons why science and art represent a winning combination in educational contexts are: (1) 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 [31]. (2) Gardner [32,33] has revealed 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 [3] we focused on how dance can be involved in informatics education (sorting algorithms). The method takes additional multi-sensory elements into the programming education through arts (dance, music, rhythm, theatrical role-playing). Combining these art forms teachers could create a multi-sensory learning environment that involves almost all senses: visual, auditory, kinaesthetic, and tactile. We invited students who like dancing to collaborate in our project. They played the roles of the numbers from the sequence to be sorted. Each of them wore the corresponding number on their dress. The accompanying music pieces were composed on the basis of Michael Flatley's music. Consulting with the eurhythmics teacher of the faculty we chose proper dance-steps for comparing and swapping operations. Once these dance-performances were videotaped we add to the records further graphical elements in order to emphasize that the dancer-numbers are stored in an array, and to highlight the dancer-pair in the focus.

Research results described in [3] support our conclusion that the presented method and multimedia software-tool may improve informatics education and bring teachers/students closer to Comenius's dream, that teaching/learning should be entirely practical, entirely pleasurable, and such as to make school a real game, i.e., a pleasant prelude to our whole life [34].



Bubble-sort dance-performance.

Multi- and inter-cultural Informatics Education

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. In [4] we particularly focused on multicultural content integration in informatics education through art-based pedagogical tools. We initiated collaboration with a professional art institution and Romanian, Hungarian, German and Gipsy (illustrating the cultural diversity in Transylvania, Romania) folk-dance choreographies were designed to illustrate different sorting algorithms. The fruits of this collaboration were such art-science productions which equally promote multiculturalism and informatics education. In order to test the potential "algorithmic dances" have in promoting intercultural informatics education we posted them on the YouTube website. Users' reactions confirmed our expectations. (http://www.youtube.com/algorythmics)

Promoting algorithmic thinking of all students

Some authors speak about science-oriented and humanities-oriented learners according to their different ways of viewing the world and their different approaches to problem-solving. These and other findings suggest that whereas algorithmic thinking is important for all students, it could be less familiar to humanities oriented learners than to their sciences oriented colleagues.

Algorithmic thinking is a specialized problem solving competence utilizing several abilities and is influenced by many other human cognitive factors, such as abstract and logical thinking, thinking in structures, creativity etc. [35]. Computer algorithms incorporate several invisible factors and abstractions, and students usually have no real-life references regarding them [36]. Additionally, computer programming frequently involves sequential algorithms designed for machines, based on a limited set of elementary instructions. For humans it is natural to cooperate, to act in parallel and to processes a large set of high level instructions [37]. All of these factors make algorithmic thinking hard to develop and incorporate into the requirement for good didactical approaches.

In [4] we presented experiment results revealing that properly calibrated learning tools can effectively promote the algorithmic thinking of both science-oriented and humanities-oriented students. The e-learning environment we developed had been designed to introduce students to the mini-world of sorting algorithms (bubble-sort, insertion-sort, selection-sort, shell-sort, quick-sort, merge-sort). The software tool generates a five-phase learning experience: the algorithm is visualized by a videotaped "sequence of folk dancers" wearing the numbers to be sorted on their dresses (1); the algorithm is animated on a white-box array (storing the number-sequence) (2); followed by student reconstructed (3) and orchestrated (4) animations; students are invited to orchestrate the studied sorting algorithm on a black-box array (being informed about the results of the comparison operations) (5). The application provides an excellent opportunity for a gentle introduction to several algorithm related concepts (best, worst and average case, algorithm complexity, etc). (http://algo-rythmics.ms.sapientia.ro/)

We have proposed to implement the following motivational strategy. During the "dance-performance phase" (1) the focus is on arousing curiosity by combining science with art and modern with traditional. The role of the "animation phase" (2) is to help students focus on the key elements of the algorithm and to prepare them for the "doing phases". During the "doing phases" of the e-learning session students are invited to actively participate in the animations according to the principle of moderate-progressive challenge. According to the constructivist learning theory, applying the knowledge they have just gained may result in more effective learning. The tasks of "doing phases" were to:

- (3) reconstruct the operation (compare, swap) sequence of the observed animation;
- (4) orchestrate the studied sorting algorithm on randomly generated input sequences stored in white-box arrays;
- (5) orchestrate the algorithm on sequences stored in black-box arrays.

Evidence of availability

We have made the above presented didactical methods and tools available to the teaching community in the following ways:

Research papers in leading scientific journals:

- On the role of senses in education (2008). *Computers & Education*, 51(4), 1707–1717.
- Technologically and artistically enhanced multi-sensory computer programming education (2010). *Teaching and teacher education*. 26, 244–251.
- Multi-sensory method for teaching-learning recursion (2011). *Computer Applications in Engineering Education*, 19(2), 234–243.
- Cultivating algorithmic thinking: an important issue for both technical and HUMAN sciences (2011), *Teaching Mathematics and Computer Science*, 9(1), 1-10.
- The challenge of promoting algorithmic thinking of both sciences and humanities oriented learners (2013). *Journal of Computer Assisted Learning*. (Under review)

- 17 citations of the above listed papers.

Conference papers (in Proceedings of conferences in informatics education):

- Algo-rythmics, *Szamokt 2008,* 18th International Conference In Computer Science, EMT, Şumulea-Ciuc, Romania, October 10-12, 2008.
- „Cocktail-learning" at Sapientia University, *Számokt 2009*, 19th International Conference In Computer Science, EMT, 243-246, Tirgu Mures, Romania, October 8-11, 2009.
- Bubble-sort with "Csango" folk dance, *„Mathematics, Music, Art, Architecture, Culture", Bridges Conference (Short Movie Festival)*, Coimbra, Portugal, July 30, 2011.

Conference talks

- Technologically and artistically enhanced multi-sensory computer programming education, *MatInfo 2009* (Conference organized by the Department of the Mathematics-Informatics, Sapientia University), Tg-Mureş, Romania, June 8, 2009.
- Algo-rythmics: multimedia, role playing and dance in computer programming education, *Multimedia in Education 2009*, Debrecen, Hungary, June 24-25, 2009.
- Programming education involving both sides of the brain, *INFODIDACT*, Conference in Informatic-didactics, Szombathely, Hungary, April 22-23, 2010.
- Intercultural programming education at Sapientia University, *INFODIDACT*, Conference in Informatic-didactics, Szombathely, Hungary, March 31 - April 1, 2011.
- Algorythmics: Science and art without ethnic borders, *MatInfo 2011* (Conference organized by the Department of the Mathematics-Informatics, Sapientia University), Tg-Mureş, Romania, June 5, 2011.

YouTube channel: AlgoRythmics
(https://www.youtube.com/user/AlgoRythmics)

- **1,792,999** VIEWs, **12,745** LIKEs and **4,852** SHAREs from **200** countries.

Video	Views	Estimated minutes watched	Likes
Bubble-sort with Hungarian ("Csángó") folk dance	588,067	222,580	3,439
Quick-sort with Hungarian (Küküllőmenti legényes) folk dance	430,008	413,271	4,643
Shell-sort with Hungarian (Székely) folk dance	260,651	80,906	1,622
Insert-sort with Romanian folk dance	210,312	96,172	1,389
Select-sort with Gypsy folk dance	181,443	102,023	809
Merge-sort with Transylvanian-saxon (German) folk dance	123,848	102,630	843

- **26** embedded player on other websites (edx.org, scienceblogs.de, i-programmer.info, etc)
  - **549,204** VIEWs and **212,066** estimated minutes watched

Facebook page: AlgoRythmics
(https://www.facebook.com/AlgoRythmics)

- **2,828** LIKEs from **20** countries.

AlgoRythmics website
(http://algo-rythmics.ms.sapientia.ro/)

- **2237** visits in 2,5 months.
- **1740** unique visitors, **22**% returning visitors.

Algorythmics at Yahoo Open Hack Europe 2011

- Bubble Sort: http://www.youtube.com/watch?v=h9pruk3bgj8
- Insert Sort: http://www.youtube.com/watch?v=c8Ly0bbbRJw

Seminars for informatics teachers:

Research grant “ALGO-RYTHMICS: Science and Art without ethnic frontiers” (supported by the Govern of Hungary; coordinated by Zoltan Katai) made possible to initiate informatics teachers from four primary and four secondary education institutions in multisensory informatics education:

- Bolyai Farkas High school, Targu Mures, Romania.
- Al. Papiu Ilarian National College, Targu Mures, Romania.
- Electromures School Group, Targu Mures, Romania.
- Berde Mózes Unitarian College, Targu Secuiesc, Romania.
- Ákosfalva Grade school, Ákosfalva, Romania.
- Székelyvaja Grade school, Székelyvaja, Romania.
- Harasztkerék Grade school, Harasztkerék, Romania.
- Serafin Duica Grade school, Targu Mures, Romania.

Evidence of impact

Research results certificate that the multisensory methods and software-tools we developed promote effective informatics education [1,2,3,4].

Our work culminated in the AlgoRythmics project. The fruitage of this project was six "sorting-dances" and an online e-learning tool that effectively exploit the didactical value of these dance-choreographies. In the followings we present the feedback we received from the international teaching and learning community. The sources are:

- (https://www.youtube.com/user/AlgoRythmics)
- (https://www.facebook.com/AlgoRythmics)
- (http://algo-rythmics.ms.sapientia.ro/)

Users' appreciations (extracts from users' comments: YouTube, facebook):

- The words *awesome, great, best, nice, brilliant, love, epic, cool, amazing, excellent* have been appeared more than 200 times in users' comments.
    - **4403** users marked AlgoRythmics channel as favourite.
- Selected extracts from users' comments:
    - Best channel ever!
    - Best demonstration on the web!
    - Thank you for this initiative. This is the greatest piece of art I have ever seen!
    - Entertaining and educational at the same time… also I find it incredibly amusing that the 'pointers' are the hats.
    - Aha! That would be awesome!!!! BEST IDEA EVER.
    - This is the coolest implementation of Quick-sort I've ever seen!
    - I will never look at a program the same way again.
    - You don't know anything about basic programming until you've seen this.
    - Beautiful piece of art to explain computer science, this is so EPIC! Thanks!
    - Amazing way to demonstrate the algorithm. Congratulations (many applauses)!
    - Wow! This combines two of my interests in a way I never expected. Lovely!
    - Art + Science = Intelligent entertainment.
    - The only true international language!!
    - I'm addicted to this video!

Teachers considering AlgoRythmics channel to be useful:
(extracts from users' comments: YouTube, facebook)

- I really love your work since I'm working with my university to a similar project called Algomotricity.
- I'm a computer science teacher and think that's brilliant! I think I'll give it a try next time I need to teach sort algorithms!
- Boston College CS102 sent me here.
- Awesome. Every computing student and teacher should watch this.
- This is a great way for a beginning CS student to get an intuitive understanding of how quick-sort works. Highly recommended!
- Inspire pour les course!!

- Oh my god! This is so brilliant! Do you have a downloable version? I'm gonna show this to my students, but internet is not so fancy around here.
- Awesome! I cannot wait to use with my students. I believe it is a great way to learn sorting algorithms. I became a fan of yours.
- Wunderbar! This is science that's joy! I posed the exercise to my students to extract the partitioning algorithm out of the quicksort dance.
- Pushing to have these videos shown in my University's computer science classes.
- Great way to visualize sorting algorithms and useful as an alternative to reading or classroom teaching!
- Awesome!!! I'm programmer and folklore dancer ... and that's what I call interactive learning ... great idea!

Students considering AlgoRythmics channel to be useful:
(extracts from users' comments: YouTube, facebook):

- It was so hard to learn it only with math and theories. So easy with these videos! Wonderful! Super mega nice work!
- You're awesome! I love it and my professor loves it too!
- Great work! I now understand quick sort. Thanks!
- Epic, I totally understand it now!
- Estos videos son geniales, me salvaron en un examen de programación!
- Never thought that this algorithm is understandable!
- ...I... think I actually understand...
- Man this video helped me more than my teachers …!!!
- Finally understand the quick-sort method
- HALLO an meinen Informatik-Grundkurs in Kreuznach!
- I wish my professor were this entertaining.
- This is how our algorithm and data-structure lectures should go like!
- Haha! 30 years after starting university as an IT student I finally understood quick-sort. Great visualization!
- Awesome!!! Before I watched this video I didn't understand this algorithm!
- This is perfect revision as I have my A level computing exam on Thursday.
- We watched this in computer science in school and our teacher said he found this video randomly in the internet.
- This has got to be the greatest math's lesson I've ever had!
- My final exam on trees, graphs, hash tables and all these sort algorithms is Monday, watching these kind of videos is funny and more interesting then my crappy notebook!
- I saw this in my AP computer science class a couple days ago, and now I'm hooked on this song.
- Finally someone explains it in such a way I can understand!
- We are watching select-sort right now in class. Awesome!
- Brilliant! The bubble sort dance illustrates the concept so well that our teacher shows it in class!

- If my professors did this diddy for class I would not only be amused but I'll never forget. New teaching technique? I sure hope so!
- You can visually see the Algorithm in execution. Great!
- When I have to explain quick sort in my oral exam I may just dance ...

Extracts from online articles that appreciated AlgoRythmics channel:

- http://www.i-programmer.info
    - You may well have seen many simulations of sorting algorithms that aim to show in novel ways how the algorithm works or perhaps doesn't work quite as well as it should. However I guarantee that you have never seen anything quite in the same league as the videos made by Sapientia University - they are simply crazy but in the nicest possible way. …
    - If you have been following the surreal interpretations of sorting algorithms as folk dances here is the ingenious culmination - the Quicksort, the most difficult of algorithms, complete with hats as pointers. Yes I know I claimed that it would be impossible, or if possible the result would be a modern dance the like of which we have not seen, but.... they have done it. The slightly insane dance group at Sapientia University has put together a Hungarian folk dance with steps that follow the Quicksort algorithm. It is worth noting that it takes just short of 7 minutes to sort just ten dancers which really isn't very quick; that only males take part which proves that it is a very dangerous algorithm and, oh yes, two hats are used to mark the progress of the scan! Clever stuff! Now see if you are anywhere near as clever by verifying that they are in fact dancing the Quicksort. If you need help then all I can suggest is that you keep your eye on the hats, notice exactly what happens when they meet and pay attention to the partitions that are produced. The sort of the dance has now reached Merge Sort and it's very tricky - how does it end up with the boy-girl pairing? …
- http://www.dyxuchen.com
    - The next time you're having trouble in computer science classes grasping the nature of shell sorts and bubble sorts, head over to the AlgoRythmics YouTube channel. There, a group of folk dancers are using Hungarian and Gypsy folk dance to teach people exactly how those sorting operations work, complete with graphic overlays and numbers on their chest and back to show you how the sort functions. … The whole affair is part of Sapientia University's Intercultural Computer Science Education program. If you understand the sorting algorithms that are on display, you'll really appreciate them. If you don't understand them but need to learn, you'll like them a lot. If you have no idea what's going on, at least you'll enjoy the dancing.
- http://mrhodotnet.blogspot.com
    - Absolutely brilliant series of videos interpreting the various sorting algorithms using folk dance. Nice touch on the conventions for comparisons. The videos have no voice-over or distracting subtitles and are slow enough that you can show the video and comment on each of the steps in the algorithm while it is occurring. After a few steps, have students predict what will happen next (e.g. who will dance next and who will swap places).
- http://antoniofarinha.com

- Computer-related algorithms can be quite hard to understand, and in some cases a simple visual demonstration makes it so much easier. The IT people in the audience might have seen a few of them, but I'm pretty sure none was quite as peculiar as this. AlgoRythmics, a folk-dancing group from Romania's Sapientia University, decided to show how data sorting algorithms work by showing them as dances. Bizarre, right? But strangely mesmerizing, and it sure does the trick of explaining how they work. Until now they did insert-sort, bubble-sort, select-sort and shell-sort. I hear that merge-sort and quick-sort are coming soon.

Reactions from the international teaching community:

Dear Dr Kátai,

Along with many colleagues, I have been enjoying the sorting dances you and your colleagues have produced, and I hope that one day I will go back to intro algorithms courses where I can use them!

I just wanted to suggest another version for your consideration: the parallel version of quicksort, rather than the sequential version. This would be quite nice to show how the recursion works conceptually - and also challenge the students more to keep track of how the algorithm is working, after they've mastered the sequential version.

Best regards, and congratulations on a lovely teaching idea, Julian Bradfield (Edinburgh).

--

The University of Edinburgh is a charitable body, registered in Scotland, with registration number SC005336.

References

1. Katai, Z., Juhasz, K., & Adorjani, A. K. (2008). On the role of senses in education. Computers & Education, 51(4), 1707–1717.
2. Katai, Z. (2009). Multi-sensory method for teaching-learning recursion. Computer Applications in Engineering Education, 1061–3773. doi:10.1002/cae.20305.
3. Kátai, Z., & Toth, L. (2010). Technologically and artistically enhanced multi-sensory computer programming education. Teaching and teacher education. 26, 244–251.
4. Kátai, Z. (2013). The challenge of promoting algorithmic thinking of both sciences and humanities oriented learners. Journal of Computer Assisted Learning. (Under review)
5. Voto, D., Viñas, L. M., & D'Auria, L. (2005). Multisensory interactive installation. In Sound and music computing '05, XV CIM. November 24–26, Salerno, Italy.
6. Shaywitz, S. (2003). Overcoming dyslexia: A new and complete science-based program for overcoming reading problems at any level. New York: Knopf.
7. Kavenaugh, J. F. (Ed.). (1991). The language continuum from infancy to literacy. Baltimore: York.
8. Hung, D. (2003). Supporting current pedagogical approaches with neuroscience research. Journal of Interactive Learning Research.
9. Stevens, J., & Goldberg, D. (2001). For the learners' sake: A practical guide to transform your classroom and school. Zephyr Press.

10. Staley, J. D. (2006). Imagining the Multisensory Classroom, Campus Technology, 6/6/2006. <http://www.campustechnology.com/article.aspx?aid=40941>.
11. Prensky, M. (2001) Digital Natives, Digital Immigrants. NCB University Press, 9(5), 113–118.
12. Prensky, M. (2007) Listen to the natives. Educational Leadership, 63(4), 8–13.
13. Spires, H. A., Lee, J. K., & Turner, K. A. (2008) Having our say: Middle grade student perspectives on school, technologies, and academic engagement. Journal of Research on Technology in Education, 40(4), 497–515.
14. Otta, M., & Tavella, M. (2010) Motivation and engagement in computer-based learning tasks: investigating key contributing factors. World Journal on Educational Technology, 2(1) 1–15.
15. Pedró, F. (2006) The New Millennium learners: challenging our views on ICT and learning. OECD-CERI. Retrieved November 10, 2012, from. http://www.oecd.org.
16. Palmer, D. (2005) A motivational view of constructivist-informed teaching. International Journal of Science Education, 27(15), 1853–1881.
17. Pintrich, P. R., Marx, R. W., & Boyle, R. A. (1993) Beyond cold conceptual change: The role of motivational beliefs and classroom contextual factors in the process of conceptual change. Review of Educational Research, 63, 167–199.
18. Deci, E. L., & Ryan, R. M. (1985) Intrinsic motivation and self-determination in human behavior. New York: Plenum.
19. Fair, E. M., & Silvestri, L. (1992) Effects of rewards, competition and outcome on intrinsic motivation. Journal of Instructional Psychology, 19, 3–8.
20. Martens, R. L., Gulikersw, J., & Bastiaensw, T. (2004) The impact of intrinsic motivation on e-learning in authentic computer tasks. Journal of Computer Assisted learning, 20, 368–376.
21. Lepper, M., Henderlong, J., & Iyengar, S. (2005) Intrinsic and extrinsic motivational orientations in the classroom: Age differences and academic correlates. Journal of Educational Psychology, 97, 184–196.
22. Robertson, J., & Howells, C. (2008) Computer game Design: Opportunities for successful learning. Computers & Education, 50(2), 559–578.
23. Day, H. I. (1971) The measurement of specific curiosity. In H. I. Day, D. E. Berlyne, & D. E. Hunt (Eds.), Intrinsic motivation: A new direction in education (pp. 99–112). New York: Holt, Rinehart & Winston.
24. Kashdan, T. B., Rose, P., & Fincham, F. D. (2004) Curiosity and exploration: Facilitating positive subjective experiences and personal growth opportunities. Journal of Personality Assessment, 82, 291–305.
25. Berlyne, D.E. (1960) Conflict, arousal, and curiosity. New York: McGraw Hill Book Company, Inc.
26. Keller, J. M. (1983) Motivational design of instruction. In C. M. Reigeluth (Ed.), Instructional-design theories and models (pp. 383–434). Hillsdale, NJ: Erlbaum.
27. Nakamura, J., & Csikszentmihalyi, M. (2002) The concept of flow. In C. R. Snyder & S. J. Lopez (Eds.), Handbook of positive psychology (pp. 89–105). Oxford: Oxford University Press.
28. Turner, J., & Meyer, D. (2004) A classroom perspective on the principle of moderate challenge in mathematics. The Journal of Educational Research, 97(6), 311–318.
29. Lepper, M. R., & Malone, T. W. (1987) Intrinsic motivation and instructional effectiveness in computer-based education. In R. E. Snow & M. J. Farr (Eds.),

Aptitude, learning, and instruction: III Conative and affective process analysis (pp. 255–296). Hillsdale, NJ: Erlbaum.

30. Garris, R., Ahlers, R., & Driskell, J. (2002) Games, motivation and learning: a research and practice model. Simulation and Gaming, 33, 441–467.
31. Eisenhower SCIMAST. (1997). How can research on the brain inform education.Classroom Compass, 3(2). 1–2, 10. Retrieved December 3, 2008, from. http://www.sedl.org/pubs/classroom-compass/cc_v3n2.pdf.
32. Gardner, H. (1993). Frames of mind (The tenth anniversary ed.). New York: Basic Books.
33. Gardner, H. (2000). Intelligence reframed. Multiple intelligences for the 21st century.New York: Basic Books.
34. Dobbie, A. M. O. (1986). Comenius's Pampaedia or universal education. Dover: Buckland.
35. Futschek, G. (2006) Algorithmic thinking: the key for understanding computer science. In Lecture Notes in Computer Science 4226 (pp. 159–168). Springer.
36. Ramadhan, H. A. (2000) Programming by discovery. Journal of Computer Assisted Learning, 16, 83–93.
37. Futschek, G., & Moschitz, J. (2010) Developing algorithmic thinking by inventing and playing algorithms. In Proceedings of Constructionist approaches to creative learning thinking and education (1–10). Retrieved November 10, 2012, from. http://publik.tuwien.ac.at/files/PubDat_187461.pdf.