USER INTERFACE AND INTERACTIVITY DESIGN GUIDELINES OF ALGORITHM VISUALIZATION ON MOBILE PLATFORM

AHMAD AFFANDI SUPLI

DOCTOR OF PHILOSOPHY
UNIVERSITI UTARA MALAYSIA
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Abstrak

Visualisasi Algoritma (AV) adalah alat pedagogi yang dapat membantu pelajar melihat proses algoritma secara animasi. Para pelajar boleh menonton dan memerhatikannya melalui penjelasan animasi dinamik. Kajian terdahulu menunjukkan bahawa kajian mudah alih AV masih terhad. Pelaksanaan AV di platform mudah alih masih dianggap sebagai trend baharu yang bermula pada tahun 2013. Di samping itu, garis panduan reka bentuk komprehensif bagi AV dari segi mereka bentuk antara muka pengguna (UI) dan faktor interaktiviti adalah masih terhad dan dibincangkan secara berasingan dalam kajian terdahulu. Banyak bukti dalam kajian empirikal terdahulu menunjukkan kepelbagaian strategi interaktiviti dan aspek reka bentuk UI adalah dua aspek untuk membuat alat AV yang berkesan kepada pelajar. Dalam konteks ini, kajian ini mencadangkan garis panduan berhubung reka bentuk AV pada platform mudah alih (AVOMP) yang berfungsi sebagai pendekatan sistematik yang merangkumi cadangan asas untuk pereka, pemaju, dan pensyarah bagi menghasilkan AVOMP berdasarkan dua aspek, iaitu reka bentuk UI dan interaktiviti. Oleh itu, bagi memastikan matlamat utama tercapai, beberapa sub-tujuan telah dibentuk iaitu: (a) untuk mengenal pasti cadangan yang sesuai untuk aspek reka bentuk UI dan interaktiviti AVOMP, (b) untuk membangunkan garis panduan reka bentuk AVOMP berdasarkan cadangan yang dikenal pasti iaitu reka bentuk UI dan interaktiviti, (c) untuk mengesahkan garis panduan reka bentuk yang dibangunkan AVOMP dari segi "kegunaan" melalui semakan pakar, dan (d) untuk mengukur keberkesanan AV pada platform mudah alih yang melaksanakan garis panduan reka bentuk yang dicadangkan melalui prototaip. Kajian ini menggunakan kaedah Penyelidikan Sains Reka Bentuk sebagai rangka kerja proses penyelidikan. Aktiviti pembinaan garis panduan reka bentuk AVOMP meliputi sorotan karya dan kajian perbandingan. Garis panduan reka bentuk yang dicadangkan disahkan melalui semakan pakar yang melibatkan 16 orang pakar. Keputusan dari pengujian hipotesis menyimpulkan bahawa garis panduan reka bentuk AVOMP yang dicadangkan menunjukkan keputusan signifikan kerana ia mempunyai kualiti untuk dijadikan garis panduan bagi pembangun atau pereka bentuk dan membangunkan AVOMP. Selain itu, penilaian keberkesanan prototaip AVOMP daripada 35 orang peserta melalui eksperimen makmal berasaskan ujian Taksonomi Bloom menunjukkan bahawa terdapat perbezaan yang signifikan antara pendekatan manual penyusunan pembelajaran algoritma (Pra-ujian) dan pendekatan manual penyusunan pembelajaran algoritma (Pasca-ujian). Oleh itu, kajian ini memberi sumbangan melalui tiga aspek iaitu sumbangan dari segi artifak, empirikal, dan juga teori. Dalam aspek sumbangan artifak, kajian ini menghasilkan garis panduan reka bentuk AVOMP yang terdiri daripada aspek reka bentuk UI dan interaktiviti serta susunan prototaip AVOMP algoritma. Manakala sumbangan dari segi empirikal pula menunjukkan hasil keberkesanan aplikasi AVOMP. Akhir sekali, aspek teori menyumbang kepada keberkesanan garis panduan reka bentuk AVOMP yang dibangunkan secara berstruktur dan komprehensif dibentuk dengan gabungan sekumpulan teori dan kajian empirikal dari dua aspek, iaitu reka bentuk UI dan interaktiviti.

Kata kunci: Visualisasi algoritma, platform mudah alih, garis panduan reka bentuk, taksonomi penglibatan, reka bentuk UI.

Abstract

Algorithm Visualization (AV) is a pedagogical tool that can help learners to see the animation of the step-by-step process of an algorithm. Students can watch and observe through the elaboration of dynamic animation. Previous studies show that AV mobile study is still limited. AV implementation on the mobile platform is still considered as a new trend which started in 2013. In addition, comprehensive design guidelines of AV in terms of designing user-interface (UI) and interactivity factors are still limited and discussed separately in previous studies. Even though, much evidence in previous empirical studies show that various interactivity strategies and UI design aspects are two imperative aspects to make an effective AV tool for learners. Within this context, this study proposes AV on mobile platforms (AVOMP) design guidelines that serve as a systematic approach. It includes the fundamental recommendations for designers, developer, and lecturers to produce AVOMP which are based on two aspects, namely UI design and interactivity aspects. Hence, in order to accomplish the main aim, a number of sub-objectives were formed: (a) to identify the appropriate recommendations for UI design and interactivity aspects of AVOMP, (b) to develop the design guidelines of AVOMP based on the identified recommendations of UI design and interactivity, (c) to validate the developed design guidelines of AVOMP in terms of "usefulness" through expert reviews, and (d) to measure the effectiveness of AV on mobile platform that implements the proposed design guidelines through prototype. This study adopted the Design Science Research methodology as the framework of the research process. Activities of AVOMP design guidelines construction include a literature review and a comparative study. The proposed design guidelines were validated through expert reviews, which involved 16 experts. Results of the hypothesis testing concludes that the proposed AVOMP design guidelines are significantly perceived as having quality in serving as a guideline for developers or designers to design and develop AVOMP. Moreover, the evaluation of the effectiveness of the AVOMP prototype from 35 participants through laboratory experiments based on the bloom taxonomy test shows that there is a significant difference between students learning sorting algorithms using the manual approach (Pre-Test) and the AVOMP app (Post-Test). Hence, this study makes three major contributions, namely artefact, empirical, and theoretical. In terms of artifact, this study yields AVOMP design guidelines that are comprised of UI design and interactivity aspects as well as AVOMP prototype of sorting algorithms. Meanwhile, empirical contribution shows the result of the effectiveness of AVOMP apps. Finally, the theoretical aspect contributes the novelty of the developed design guidelines of AVOMP that are structured and comprehensively formed with a combination of a bunch of theories and empirical studies of two aspects, which are UI design and interactivity.

Keywords: Algorithm visualization, mobile platform, design guidelines, engagement taxonomy, UI design.

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List of Abbreviations

DSA	Data Structure and Algorithm
AV	Algorithm Visualization
PV	Program Visualization
UI	User Interface
HCI	Human Computer Interaction
AVOMP	Algorithm Visualization on Mobile Platform
G	Guideline
ET	Engagement Taxonomy
EET	Extend Engagement Taxonomy
2DET	Two-dimensional Engagement Taxonomy
CLT	Cognitive Load Theory
GUI	Graphical User Interface
IS	Information System
IT	Information Technology
DSR	Design Science Research
ITM	Iterative Triangulation Methodology
KA	Knowledge Acquisition
CS	Computer Science
SE	Software Engineering
UUM	Universiti utara Malaysia

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CHAPTER ONE
INTRODUCTION

1.1 Overview

This introductory chapter consists of a background of study which discusses on issues that lead to the motivation of the study, explanation of the problem background, research gap, and then research objective formulation. This section also elaborates the scope and limitations of the study, significance of the study, theoretical and research framework, as well as operational definitions of terms used throughout the study.

1.2 Motivation of Study

Learning Data Structures and Algorithm (DSA) course in understanding the algorithm concept is a really challenging task in computer science education (Bäck, Fogel, & Michalewicz, 2018; Crescenzi, Malizia, Verri, Díaz, & Aedo, 2012; Osman & Elmusharaf, 2014). DSA is an important subject for students in computer science education, but it is mostly hard to learn due to the abstract nature (Sadikan & Yassin, 2012). In general, the students have difficulty in order to depict visually the step by step process that is involved in the algorithm.

According to Patel (2014), there are four main problems faced by lecturers and tutors to teach this course: first is the low motivation of students. The second problem is how to explain DSA concept, which can be tricky and abstract to students. Third, in order to do the assignment, the cooperation between students is still low. Fourth, the implementation of algorithms to implement in real life situation setting is hard to do.

References

Adamchik, V. (2011). *Data structures and algorithms in pen-based computing environments.* Paper presented at the Global Engineering Education Conference (EDUCON), 2011 IEEE.

Al-Zoubi, A., Alkouz, A., & Otair, M. (2008). Trends and Challenges for Mobile Learning in Jordan. *International Journal of Interactive Mobile Technologies, 2*(2).

Alhosban, F., & Hamad, M. (2011). *The Effectiveness of Aural Instructions with Visualisations in E-Learning Environments.* Durham University.

Ali, A. Z. M., & Derus, S. R. M. (2013). Usability and user satisfaction of hardware-software interfacing visualization kit for novice learning programming. *Procedia-Social and Behavioral Sciences, 103*, 1252-1260.

Amershi, S., Arksey, N., Carenini, G., Conati, C., Mackworth, A., Maclaren, H., & Poole, D. (2005). Fostering Student Learning and Motivation: an interactive educational tool for AI: Citeseer.

Anderson, L. W., Krathwohl, D. R., & Bloom, B. S. (2001). *A taxonomy for learning, teaching, and assessing: A revision of Bloom's taxonomy of educational objectives*: Allyn & Bacon.

Ando, M., & Ueno, M. (2008). *Cognitive load reduction on multimedia e-learning materials.* Paper presented at the Advanced Learning Technologies, 2008. ICALT'08. Eighth IEEE International Conference on.

Ariffin, A. M. (2009). *Conceptual design of reality learning media (RLM) model based on entertaining and fun constructs.* Universiti Utara Malaysia.

Attwell, G. (2012). Work-Based Mobile Learning Environments: Contributing to. *Refining Current Practices in Mobile and Blended Learning: New Applications: New Applications*, 229.

Attwell, G., Guile, D., Angelis, E. d., Scheuermann, F., Frutos, M. B., & Skulimowski, A. M. (2003). The challenge of e-learning in small enterprises: the UK Case Study: Issues for Policy and Practice in Europe.

Avancena, A. T., & Nishihara, A. (2015). Usability and pedagogical assessment of an algorithm learning tool: a case study for an introductory programming course for high school. *Issues in Informing Science & Information Technology, 12*, 21-44.

Ayres, P., & Cierniak, G. (2012). Split-Attention Effect *Encyclopedia of the Sciences of Learning* (pp. 3172-3175): Springer.

Ayres, P., & Paas, F. (2012). Cognitive load theory: New directions and challenges. *Applied Cognitive Psychology, 26*(6), 827-832.

Ayres, P., & Sweller, J. (2014). The split-attention principle in multimedia learning. *The Cambridge handbook of multimedia learning, 2*.

Aziz, N., Mutalib, A. A., & Sarif, S. M. (2017). User experience of interactive assistive courseware for low vision learners (AC4LV): Initial round. *TEM Journal, 6*(3), 488.

Bäck, T., Fogel, D. B., & Michalewicz, Z. (2018). *Evolutionary computation 1: Basic algorithms and operators*: CRC press.

Banerjee, G., Murthy, S., & Iyer, S. (2015). Effect of active learning using program visualization in technology-constrained college classrooms. *Research and Practice in Technology Enhanced Learning, 10*(1), 1.

Bansemir, B. (2013). Research paradigm *Organizational Innovation Communities* (pp. 9-11): Springer.

Basoglu, E. B., & Akdemir, Ö. (2010). A comparison of undergraduate students' English vocabulary learning: Using mobile phones and flash cards. *TOJET: The Turkish Online Journal of Educational Technology, 9*(3).

Benitti, F. B. V., & Sommariva, L. (2015). Evaluation of a game used to teach usability to undergraduate students in computer science. *Journal of Usability Studies, 11*(1), 21-39.

Bhagyalakshmi, H., & Seshachalam, D. (2015). Student performance using Blooms cognition levels: A case study. *Journal of Engineering Education Transformations*, 122-125.

Block, G. (2013). *Reducing Cognitive Load Using Adaptive Uncertainty Visualization.* Nova Southeastern University.

Boticki, I., Barisic, A., Martin, S., & Drljevic, N. (2013). Teaching and learning computer science sorting algorithms with mobile devices: A case study. *Computer Applications in Engineering Education, 21*(S1), E41-E50.

Boy, J., Detienne, F., & Fekete, J.-D. (2015). *Storytelling in Information Visualizations: Does it Engage Users to Explore Data?* Paper presented at the Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems.

Bradley, C., Haynes, R., Cook, J., Boyle, T., & Smith, C. (2009). Design and development of multimedia learning objects for mobile phones. *Mobile learning: Transforming the delivery of education and training*, 157-182.

Brandse, M., & Tomimatsu, K. (2014). *Using color guidance to improve on usability in interactive environments.* Paper presented at the International Conference on Human-Computer Interaction.

Brunken, R., Plass, J. L., & Leutner, D. (2003). Direct measurement of cognitive load in multimedia learning. *Educational Psychologist, 38*(1), 53-61.

Buchanan, G., Farrant, S., Jones, M., Thimbleby, H., Marsden, G., & Pazzani, M. (2001). *Improving mobile internet usability.* Paper presented at the Proceedings of the 10th international conference on World Wide Web.

Burguillo, J. C. (2010). Using game theory and competition-based learning to stimulate student motivation and performance. *Computers & Education, 55*(2), 566-575.

Büyükduman, İ., & Şirin, S. (2010). Learning portfolio (LP) to enhance constructivism and student autonomy. *Procedia-Social and Behavioral Sciences, 3*, 55-61.

Campbell, D. T., & Stanley, J. C. (2015). *Experimental and quasi-experimental designs for research*: Ravenio Books.

Chandran, S. (2010). E-education in multicultural setting: The success of mobile learning. *World Academy of Science, Engineering and Technology, International Journal of Social, Behavioral, Educational, Economic, Business and Industrial Engineering, 4*(10), 2049-2053.

Chang, T.-R., Kaasinen, E., & Kaipainen, K. (2012). *Persuasive design in mobile applications for mental well-being: multidisciplinary expert review.* Paper presented at the International Conference on Wireless Mobile Communication and Healthcare.

Che, P.-C., Lin, H.-Y., Jang, H.-C., Lien, Y.-N., & Tsai, T.-C. (2009). A study of English mobile learning applications at National Chengchi University. *International Journal of Distance Education Technologies (IJDET), 7*(4), 38-60.

Chen, C.-H., & Chien, Y.-H. (2005). Reading Chinese text on a small screen with RSVP. *Displays, 26*(3), 103-108.

Chen, I.-J., & Chang, C.-C. (2011). Content presentation modes in mobile language listening tasks: English proficiency as a moderator. *Computer Assisted Language Learning, 24*(5), 451-470.

Churchill, D. (2011). Conceptual Model Learning Objects and Design Recommendations for Small Screens. *Educational Technology & Society, 14*(1), 203-216.

Churchill, D., & Hedberg, J. (2008). Learning object design considerations for small-screen handheld devices. *Computers & Education, 50*(3), 881-893.

Ciampa, K. (2014). Learning in a mobile age: an investigation of student motivation. *Journal of Computer Assisted Learning, 30*(1), 82-96.

Cierniak, G., Scheiter, K., & Gerjets, P. (2009). Explaining the split-attention effect: Is the reduction of extraneous cognitive load accompanied by an increase in germane cognitive load? *Computers in Human Behavior, 25*(2), 315-324.

Clark, R. C., Nguyen, F., & Sweller, J. (2011). *Efficiency in learning: Evidence-based guidelines to manage cognitive load*: John Wiley & Sons.

Cockburn, A., Ahlström, D., & Gutwin, C. (2012). Understanding performance in touch selections: Tap, drag and radial pointing drag with finger, stylus and mouse. *International Journal of Human-Computer Studies, 70*(3), 218-233.

Cooper, M. L., Shaffer, C. A., Edwards, S. H., & Ponce, S. P. (2014). Open source software and the algorithm visualization community. *Science of Computer Programming, 88*, 82-91.

Cooperstein, S. E., & Kocevar-Weidinger, E. (2004). Beyond active learning: a constructivist approach to learning. *Reference Services Review, 32*(2), 141-148.

Corder, G. W., & Foreman, D. I. (2014). *Nonparametric statistics: A step-by-step approach*: John Wiley & Sons.

Crescente, M. L., & Lee, D. (2011). Critical issues of m-learning: design models, adoption processes, and future trends. *Journal of the Chinese Institute of Industrial Engineers, 28*(2), 111-123.

Crescenzi, P., Malizia, A., Verri, M. C., Díaz, P., & Aedo, I. (2012). Integrating Algorithm Visualization Video into a First-Year Algorithm and Data Structure Course. *Educational Technology & Society, 15*(2), 115-124.

Crompton, H., & Burke, D. (2018). The use of mobile learning in higher education: A systematic review. *Computers & Education, 123*, 53-64.

Cross, N. (2001). Designerly ways of knowing: Design discipline versus design science. *Design issues, 17*(3), 49-55.

Dahlstrom, E., Walker, J., & Dziuban, C. (2013). ECAR study of undergraduate students and information technology: 2013.

del Vado Vírseda, R. (2010). *A visualization tool for tutoring the interactive learning of data structures and algorithmic schemes. NOTE FROM ACM: It has been determined that the author of this article plagiarized the contents from a previously published paper. Therefore ACM has shut off access to this paper.* Paper presented at the Proceedings of the 41st ACM technical symposium on Computer science education.

Delgado-Almonte, M., Andreu, H. B., & Pedraja-Rejas, L. (2010). Information technologies in higher education: Lessons learned in industrial engineering. *Educational Technology & Society, 13*(4), 140-154.

Deller, M., Ebert, A., Bender, M., Agne, S., & Barthel, H. (2007). *Preattentive visualization of information relevance.* Paper presented at the Proceedings of the international workshop on Human-centered multimedia.

Demirbilek, M., & Demirel, S. (2010). Investigating attitudes of adult educators towards educational mobile media and games in eight European countries. *Journal of Information Technology Education, 9*(1), 235-247.

Derus, S. R. M., & Ali, A. Z. M. (2015). *Utilizing program visualization in learning hardware programming: Effects of engagement level.* Paper presented at the Information and Communication Technology Convergence (ICTC), 2015 International Conference on.

Duin, A. H., Anklesaria, F., & Nater, E. (2012). Cultivating Change in the Academy: 50+ Stories from the Digital Frontlines at the University of Minnesota in 2012.

Eliasson, J., Pargmann, T. C., Nouri, J., Spikol, D., & Ramberg, R. (2013a). Mobile devices as support rather than distraction for mobile learners: Evaluating guidelines for design *Innovations in Mobile Educational Technologies and Applications* (pp. 61-76): IGI Global.

Eliasson, J., Pargmann, T. C., Nouri, J., Spikol, D., & Ramberg, R. (2013b). Mobile devices as support rather than distraction for mobile learners: Evaluating guidelines for design. *Innovations in mobile educational technologies and applications*.

Fiorella, L., & Mayer, R. E. (2014). Role of expectations and explanations in learning by teaching. *Contemporary Educational Psychology, 39*(2), 75-85.

Fling, B. (2009). *Mobile Design and Development: Practical concepts and techniques for creating mobile sites and web apps*: " O'Reilly Media, Inc.".

Florax, M., & Ploetzner, R. (2010). What contributes to the split-attention effect? The role of text segmentation, picture labelling, and spatial proximity. *Learning and Instruction, 20*(3), 216-224.

Forehand, M. (2010). Bloom's taxonomy. *Emerging perspectives on learning, teaching, and technology*, 41-47.

Foutsitzis, C. G., & Demetriadis, S. (2013). Scripted collaboration to leverage the impact of algorithm visualization tools in online learning: Results from two small scale studies. *International Journal of e-Collaboration (IJeC), 9*(1), 42-56.

Giordano, J. C., & Carlisle, M. (2006). *Toward a more effective visualization tool to teach novice programmers.* Paper presented at the Proceedings of the 7th conference on Information technology education.

Gong, J., & Tarasewich, P. (2004). *Guidelines for handheld mobile device interface design.* Paper presented at the Proceedings of DSI 2004 Annual Meeting.

Goodrich, M. T., & Tamassia, R. (2008). *Data structures and algorithms in Java*: John Wiley & Sons.

Graham, L. (2008). Gestalt theory in interactive media design. *Journal of Humanities & Social Sciences, 2*(1).

Grissom, S., McNally, M. F., & Naps, T. (2003). *Algorithm visualization in CS education: comparing levels of student engagement.* Paper presented at the Proceedings of the 2003 ACM symposium on Software visualization.

Guberman, S., Maximov, V. V., & Pashintsev, A. (2012). Gestalt and Image Understanding. *Gestalt Theory, 34*(2), 143.

Guney, A., & Al, S. (2012). Effective learning environments in relation to different learning theories. *Procedia-Social and Behavioral Sciences, 46*, 2334-2338.

Hadjerrouit, S. (2005). Constructivism as guiding philosophy for software engineering education. *ACM SIGCSE Bulletin, 37*(4), 45-49.

Halim, S., Koh, Z. C., Loh, V., & Halim, F. (2012). Learning Algorithms with Unified and Interactive Web-Based Visualization. *Olympiads in Informatics, 6*, 53-68.

Hanley, M. (2010). A Media Model for E-Learning Content: Project Lifecycle 4. *E-Learning Curve Blog*.

Hansen, S. R., & Narayanan, N. H. (2013). *On the role of animated analogies in algorithm visualizations.* Paper presented at the Proceedings of the Fourth International Conference of The Learning Sciences.

Haroz, S., Kosara, R., & Franconeri, S. L. (2015). *Isotype visualization: Working memory, performance, and engagement with pictographs.* Paper presented at the Proceedings of the 33rd annual ACM conference on human factors in computing systems.

Hassanabadi, H., Robatjazi, E. S., & Savoji, A. P. (2011). Cognitive consequences of segmentation and modality methods in learning from instructional animations. *Procedia-Social and Behavioral Sciences, 30*, 1481-1487.

Hevner, A. R. (2007). A three cycle view of design science research. *Scandinavian journal of information systems, 19*(2), 4.

Hevner, A. R., March, S. T., Park, J., & Ram, S. (2004). Design science in information systems research. *MIS quarterly, 28*(1), 75-105.

Hoehle, H., Aljafari, R., & Venkatesh, V. (2016). Leveraging Microsoft′ s mobile usability guidelines: Conceptualizing and developing scales for mobile application usability. *International Journal of Human-Computer Studies, 89*, 35-53.

Holzinger, A. (2005). Usability engineering methods for software developers. *Communications of the ACM, 48*(1), 71-74.

Hong, S., & Kim, S. C. (2011). *Mobile web usability: developing guidelines for mobile web via smart phones.* Paper presented at the International Conference of Design, User Experience, and Usability.

Huber, P. (2015). Inaccurate input on touch devices relating to the fingertip. *Media Informatics Proseminar on" Interactive Surfaces, 31*.

Hübscher-Younger, T., & Narayanan, N. H. (2003). *Dancing hamsters and marble statues: characterizing student visualizations of algorithms.* Paper presented at the Proceedings of the 2003 ACM symposium on Software visualization.

Hujainah, F., Dahlan, H., Al-Haimi, B., Hujainah, A., Al-Bashiri, H., & Abdulgabber, M. A. (2016). New Usability Guidelines with Implementation Ways of Mobile Learning Application based on Mobile Learning Usability Attributes. *Indian Journal of Science and Technology, 9*(37).

Hundhausen, C., & Douglas, S. (2002). A language and system for constructing and presenting low fidelity algorithm visualizations *Software Visualization* (pp. 227-240): Springer.

Hundhausen, C. D., & Brown, J. L. (2008). Designing, visualizing, and discussing algorithms within a CS 1 studio experience: An empirical study. *Computers & Education, 50*(1), 301-326.

Hundhausen, C. D., Douglas, S. A., & Stasko, J. T. (2002). A meta-study of algorithm visualization effectiveness. *Journal of Visual Languages & Computing, 13*(3), 259-290.

Hwang, G.-J., & Wu, P.-H. (2014). Applications, impacts and trends of mobile technology-enhanced learning: a review of 2008–2012 publications in selected SSCI journals. *International Journal of Mobile Learning and Organisation, 8*(2), 83-95.

Hwang, G. J., Shi, Y. R., & Chu, H. C. (2011). A concept map approach to developing collaborative Mindtools for context-aware ubiquitous learning. *British Journal of Educational Technology, 42*(5), 778-789.

Ismail, I., Baharum, H., & Idrus, R. (2010). Simplistic is the ingredient for mobile learning. *International Journal of Interactive Mobile Technologies, 4*(3), 4-8.

Jackson, I. (2008). Gestalt-A Learning Theory for Graphic Design Education. *International Journal of Art & Design Education, 27*(1), 63-69.

Jin, S.-H. (2013). Visual design guidelines for improving learning from dynamic and interactive digital text. *Computers & Education, 63*, 248-258.

Jonathan, F. C., Karnalim, O., & Ayub, M. (2016). *Extending The Effectiveness of Algorithm Visualization with Performance Comparison through Evaluation-integrated Development.* Paper presented at the Seminar Nasional Aplikasi Teknologi Informasi (SNATI).

Juett, J. A. (2016). Using Program Visualization to Illuminate the Notional Machine.

Karam, A. M. (2015). *A comparison of the effects of mobile device display size and orientation, and text segmentation on learning, cognitive load, and user perception in a higher education chemistry course.*

Karavirta, V., Korhonen, A., Malmi, L., & Naps, T. (2010). A comprehensive taxonomy of algorithm animation languages. *Journal of Visual Languages & Computing, 21*(1), 1-22.

Karavirta, V., & Shaffer, C. (2015). Creating Engaging Online Learning Material with the JSAV JavaScript Algorithm Visualization Library.

Karavirta, V., & Shaffer, C. A. (2013). *JSAV: the JavaScript algorithm visualization library.* Paper presented at the Proceedings of the 18th ACM conference on Innovation and technology in computer science education.

Keeney, R. L., & von Winterfeldt, D. (1991). Eliciting probabilities from experts in complex technical problems. *IEEE Transactions on engineering management, 38*(3), 191-201.

Kim, J., Kang, P., & Choi, I. (2014). Pleasure now, meaning later: Temporal dynamics between pleasure and meaning. *Journal of Experimental Social Psychology, 55*, 262-270.

Kölling, M. (2008). Using BlueJ to introduce programming *Reflections on the Teaching of Programming* (pp. 98-115): Springer.

Koole, M. L. (2009). A model for framing mobile learning. *Mobile learning: Transforming the delivery of education and training, 1*(2), 25-47.

Korhonen, A., Laakso, M.-J., & Myller, N. (2009). HOW DOES ALGORITHM VISUALIZATION AFFECT COLLABORATION?

Krebs, M., Lauer, T., Ottmann, T., & Trahasch, S. (2005). *Student-built algorithm visualizations for assessment: flexible generation, feedback and grading.* Paper presented at the ACM SIGCSE Bulletin.

Kukulska-Hulme, A., Pettit, J., Bradley, L., Carvalho, A. A., Herrington, A., Kennedy, D., & Walker, A. (2011). Mature students using mobile devices in life and learning.

Kurby, C. A., & Zacks, J. M. (2008). Segmentation in the perception and memory of events. *Trends in cognitive sciences, 12*(2), 72-79.

Laakso, M.-J., Myller, N., & Korhonen, A. (2009). Comparing Learning Performance of Students Using Algorithm Visualizations Collaboratively on Different Engagement Levels. *Educational Technology & Society, 12*(2), 267-282.

Lantz, B., Andersson, R., & Manfredsson, P. (2016). Preliminary Tests of Normality When Comparing Three Independent Samples. *Journal of Modern Applied Statistical Methods, 15*(2), 11.

Lazaridis, V., Samaras, N., & Sifaleras, A. (2013). An empirical study on factors influencing the effectiveness of algorithm visualization. *Computer Applications in Engineering Education, 21*(3), 410-420.

Leavitt, M. O., & Shneiderman, B. (2006). Research-based web design & usability guidelines. *US Department of Health and Human Services*.

Lee, K. B., & Grice, R. A. (2004). *Developing a new usability testing method for mobile devices.* Paper presented at the Professional Communication Conference, 2004. IPCC 2004. Proceedings. International.

Lee, M.-H., & Rößling, G. (2010). *Integrating categories of algorithm learning objective into algorithm visualization design: a proposal.* Paper presented at the Proceedings of the fifteenth annual conference on Innovation and technology in computer science education.

Lee, M.-H., & Rößling, G. (2011). *Constructivist and Constructionist Approaches to Constructing Algorithm Visualizations: A Proposal.* Paper presented at the 2011 11th IEEE International Conference on Advanced Learning Technologies.

Leppink, J., Paas, F., Van Gog, T., van Der Vleuten, C. P., & Van Merrienboer, J. J. (2014). Effects of pairs of problems and examples on task performance and different types of cognitive load. *Learning and Instruction, 30*, 32-42.

Lister, R., Box, I., Morrison, B., Tenenberg, J., & Westbrook, D. S. (2004). *The dimensions of variation in the teaching of data structures.* Paper presented at the ACM SIGCSE Bulletin.

Liu, M., Geurtz, R., Karam, A., Navarrete, C., & Scordino, R. (2013). Research on mobile learning in adult education. *On the move: Mobile learning for development. Charlotte, NC: Information Age Publishing*.

Liu, T.-C., Lin, Y.-C., Tsai, M.-J., & Paas, F. (2012). Split-attention and redundancy effects on mobile learning in physical environments. *Computers & Education, 58*(1), 172-180.

Liu, T. C., Lin, Y. C., & Paas, F. (2013). Effects of cues and real objects on learning in a mobile device supported environment. *British Journal of Educational Technology, 44*(3), 386-399.

Luong, M. G., & McLaughlin, A. C. (2009). *Bar Graphs and Small Screens: Mitigating Cognitive Load in Mobile Visualizations.* Paper presented at the Proceedings of the Human Factors and Ergonomics Society Annual Meeting.

Mahmoud, A. K. A., & Kamel, A. (2014). The effect of using discovery learning strategy in teaching grammatical rules to first year general secondary student on developing their achievement and metacognitive skills. *International Journal of Innovation and Scientific Research, 5*(2), 146-153.

Maniar, N., Bennett, E., Hand, S., & Allan, G. (2008). The effect of mobile phone screen size on video based learning. *Journal of software, 3*(4), 51-61.

Marx, A., Backes, C., Meese, E., Lenhof, H.-P., & Keller, A. (2016). EDISON-WMW: exact dynamic programing solution of the Wilcoxon–Mann–Whitney test. *Genomics, proteomics & bioinformatics, 14*(1), 55-61.

Mayer, R., & Moreno, R. (2002). Aids to computer-based multimedia learning. Learning and Introduction, 12, 107-119.

Mayer, R. E. (2002). Multimedia learning. *Psychology of Learning and Motivation, 41*, 85-139.

Mayer, R. E. (2009). *Multimedia learning*: Cambridge university press.

Mayer, R. E. (2014). Cognitive theory of multimedia learning. *The Cambridge handbook of multimedia learning, 43*.

Mayer, R. E., Bove, W., Bryman, A., Mars, R., & Tapangco, L. (1996). When less is more: Meaningful learning from visual and verbal summaries of science textbook lessons. *Journal of educational psychology, 88*(1), 64.

Mayer, R. E., & Chandler, P. (2001). When learning is just a click away: Does simple user interaction foster deeper understanding of multimedia messages? *Journal of educational psychology, 93*(2), 390.

Mayer, R. E., & Moreno, R. (2003). Nine ways to reduce cognitive load in multimedia learning. *Educational psychologist, 38*(1), 43-52.

McGee, S., McGee-Tekula, R., Duck, J., White, T., Greenberg, R. I., Dettori, L., . . . Rasmussen, A. (2016). *Does a taste of computing increase Computer Science enrollment?* Paper presented at the Research on Equity and Sustained Participation in Engineering, Computing, and Technology (RESPECT), 2016.

Mehlhorn, K. (2013). *Data structures and algorithms 1: Sorting and searching* (Vol. 1): Springer Science & Business Media.

Meolic, R. (2013). *Demonstration of Sorting Algorithms on Mobile Platforms.* Paper presented at the CSEDU.

Meolic, R., & Dogša, T. (2014). A C++ App for Demonstration of Sorting Algorithms on Mobile Platforms. *International Journal of Interactive Mobile Technologies (iJIM), 8*(1), pp. 40-45.

Meyers, S. (2004). The most important design guideline?[user interfaces]. *Software, IEEE, 21*(4), 14-16.

Mirkovic, J., Bryhni, H., & Ruland, C. M. (2011). Designing user friendly mobile application to assist cancer patients in illness management.

Moere, A. V., Tomitsch, M., Wimmer, C., Christoph, B., & Grechenig, T. (2012). Evaluating the effect of style in information visualization. *IEEE transactions on visualization and computer graphics, 18*(12), 2739-2748.

Molina, A. I., Redondo, M. A., Lacave, C., & Ortega, M. (2014). Assessing the effectiveness of new devices for accessing learning materials: An empirical analysis based on eye tracking and learner subjective perception. *Computers in Human Behavior, 31*, 475-490.

Moons, J., & De Backer, C. (2013). The design and pilot evaluation of an interactive learning environment for introductory programming influenced by cognitive load theory and constructivism. *Computers & Education, 60*(1), 368-384.

Moreno, A., & Joy, M. S. (2007). Jeliot 3 in a demanding educational setting. *Electronic Notes in Theoretical Computer Science, 178*, 51-59.

Mostakhdemin-Hosseini, A. (2009a). Analysis of Pedagogical Considerations of M-Learning in Smart Devices. *International Journal of Interactive Mobile Technologies, 3*(4).

Mostakhdemin-Hosseini, A. (2009b). Analysis of Pedagogical Considerations of M-Learning in Smart Devices. *iJIM, 3*(4), 33-34.

MQA, M. Q. A. (2018). *GUIDELINES: MALAYSIAN QUALIFICATION STATEMENT (MQS)*.

Mulvey, M. (2015). *Effects of visualization on algorithm comprehension.* The University of Wisconsin-Milwaukee.

Myller, N., Bednarik, R., Sutinen, E., & Ben-Ari, M. (2009). Extending the engagement taxonomy: Software visualization and collaborative learning. *ACM Transactions on Computing Education (TOCE), 9*(1), 7.

Myller, N., Laakso, M., & Korhonen, A. (2007). *Analyzing engagement taxonomy in collaborative algorithm visualization.* Paper presented at the ACM SIGCSE Bulletin.

Najima, D., & Rachida, A. (2008). An Adaptation of E-learning Standards to M-learning. *International Journal of Interactive Mobile Technologies, 2*(3).

Naps, T. L. (2005). Jhavé: Supporting algorithm visualization. *Computer Graphics and Applications, IEEE, 25*(5), 49-55.

Naps, T. L., Rößling, G., Almstrum, V., Dann, W., Fleischer, R., Hundhausen, C., . . . Rodger, S. (2002). *Exploring the role of visualization and engagement in computer science education.* Paper presented at the ACM Sigcse Bulletin.

Nathan, R. J., & Yeow, P. H. (2011). Crucial web usability factors of 36 industries for students: a large-scale empirical study. *Electronic Commerce Research, 11*(2), 151-180.

Neil, T. (2014). *Mobile design pattern gallery: UI patterns for smartphone apps*: " O'Reilly Media, Inc.".

Nielsen, J. (1997). The use and misuse of focus groups. *IEEE software, 14*(1), 94-95.

Nikander, J., Korhonen, A., Seppälä, O., Karavirta, V., Silvasti, P., & Malmi, L. (2004). Visual algorithm simulation exercise system with automatic assessment: TRAKLA2. *Informatics in Education-An International Journal*(Vol 3_2), 267-288.

Nilsson, E. G. (2008). Design guidelines for mobile applications. *SINTEF ICT, Jun*.

Norshuhada, S., & Shahizan, H. (2010). Design Research in Software Development: Constructing and Linking Research Questions, Objectives, Methods and Outcomes: Sintok: Penerbit Universiti Utara Malaysia.

Norsuhada, S., & Shahizan, H. (2010). *Design Research in Software Development: Constructing, Linking Research Questions, Objective, Methods and Outcomes* (U. U. Malaysia Ed.). Sintok: Universiti Utara Malaysia.

Nurulnadwan, A., Ariffin, M., & Mahfuzah, S. S. (2015). Expert review conceptual design and development model of assistive courseware for young low vision (AC4LV) learners. *Int. J. Conceptions Manag. Soc. Sci, 3*(2), 35-39.

O'Malley, C., Vavoula, G., Glew, J., Taylor, J., Sharples, M., Lefrere, P., . . . Waycott, J. (2005). Guidelines for learning/teaching/tutoring in a mobile environment.

Offermann, P., Levina, O., Schönherr, M., & Bub, U. (2009). *Outline of a design science research process.* Paper presented at the Proceedings of the 4th International Conference on Design Science Research in Information Systems and Technology.

Orlikowski, W. J., & Iacono, C. S. (2001). Research commentary: Desperately seeking the" it" in it research—a call to theorizing the it artifact. *Information systems research, 12*(2), 121-134.

Osman, W. I., & Elmusharaf, M. M. (2014). Effectiveness of Combining Algorithm and Program Animation: A Case Study with Data Structure Course. *Issues in Informing Science and Information Technology, 11*.

Paas, F., & Sweller, J. (2014). 2 Implications of Cognitive Load Theory for Multimedia Learning. *The Cambridge Handbook of Multimedia Learning*, 27.

Page, T. (2014). Application-based mobile devices in design education. *International Journal of Mobile Learning and Organisation, 8*(2), 96-111.

Park, H. M. (2015). Univariate analysis and normality test using SAS, Stata, and SPSS.

Park, Y. (2011). A pedagogical framework for mobile learning: Categorizing educational applications of mobile technologies into four types. *The International Review of Research in Open and Distributed Learning, 12*(2), 78-102.

Patel, S. (2014). A Literature Review on Tools for Learning Data Structures.

Pathania, U., & Singh, A. (2014). Visualization Tools of Data Structures Algorithms – A Survey. *International Journal of Advanced Research in Computer Science and Software Engineering, 4*(3), 338-341.

Patil, V. H. (2012). *Data Structures Using C++*: Oxford University Press, Inc.

Pea, R. D., & Maldonado, H. (2006). WILD for learning: Interacting through new computing devices anytime, anywhere. *The Cambridge handbook of the learning sciences*, 852-886.

Peffers, K., Tuunanen, T., Rothenberger, M. A., & Chatterjee, S. (2007). A design science research methodology for information systems research. *Journal of management information systems, 24*(3), 45-77.

Pimmer, C., Pachler, N., & Attwell, G. (2010). Towards work-based mobile learning: what we can learn from the fields of work-based learning and mobile learning. *International journal of mobile and blended learning, 2*(4), 1-18.

Posavac, E. J. (2015). *Program evaluation: Methods and case studies*: Routledge.

Puteh, M., Adnan, M., Ibrahim, M. H., Noh, N. M., & Che'Ahmad, C. N. (2014). An analysis of comfortable teaching and learning environment: Community response to climate change in school. *Procedia-Social and Behavioral Sciences, 116*, 285-290.

Ragonis, N. (2012). Type of questions–the case of computer science. *Olympiads in Informatics, 6*, 115-132.

Ramli, N., & Habib, A. (2013). A SURVEY OF PROGRAMMING LANGUAGE COURSES IN MALAYSIA'S PUBLIC UNIVERSITIES. *INTED2013 Proceedings*, 4086-4095.

Repokari, L., Saarela, T., & Kurki, I. (2002). *Visual search on a mobile phone display.* Paper presented at the Proceedings of the 2002 annual research conference of the South African institute of computer scientists and information technologists on Enablement through technology.

Richardson, R. T., Drexler, T. L., & Delparte, D. M. (2014). Color and contrast in E-Learning design: A review of the literature and recommendations for instructional designers and web developers. *Journal of Online Learning and Teaching, 10*(4), 657.

Rogers, Y., Sharp, H., & Preece, J. (2011). *Interaction design: beyond human-computer interaction*: John Wiley & Sons.

Ross, J., & Gao, J. (2016). Overcoming the language barrier in mobile user interface design: A case study on a mobile health app. *arXiv preprint arXiv:1605.04693*.

Rößling, G., & Freisleben, B. (2002). ANIMAL: A system for supporting multiple roles in algorithm animation. *Journal of Visual Languages & Computing, 13*(3), 341-354.

Rößling, G., & Naps, T. L. (2002). A testbed for pedagogical requirements in algorithm visualizations. *ACM SIGCSE Bulletin, 34*(3), 96-100.

Rubel, C., & Wallace, M. (2013). *Cognitive Load and Online Learning-When is Working Memory Capacity Exceeded?* Paper presented at the World Conference on Educational Multimedia, Hypermedia and Telecommunications.

Sadikan, S. F. N., & Yassin, S. F. M. (2012). Role of Interactive Computer Programming Courseware in Facilitating Teaching and Learning Process Based on Perception of Students in Bangi, Selangor, Malaysia. *Learning, 3*, 0.51.

Sadikan, S. F. N., & Yassin, S. F. M. (2013). A Conceptual Framework for C Programming Learning Through Basic Game Development Courseware. *International Journal of Scientific & Engginering Research, 4*(8).

Saltan, F. (2016). The Impact of Online Algorithm Visualization on ICT Students' Achievements in Introduction to Programming Course. *Journal of Education and Learning, 6*(1), 184.

Sanchez, C. A., & Branaghan, R. J. (2011). Turning to learn: Screen orientation and reasoning with small devices. *Computers in Human Behavior, 27*(2), 793-797.

Sanchez, C. A., & Goolsbee, J. Z. (2010). Character size and reading to remember from small displays. *Computers & Education, 55*(3), 1056-1062.

Sanchez, C. A., & Wiley, J. (2009). To scroll or not to scroll: Scrolling, working memory capacity, and comprehending complex texts. *Human Factors: The Journal of the Human Factors and Ergonomics Society, 51*(5), 730-738.

Savoji, A. P., Hassanabadi, H., & Fasihipour, Z. (2011). The modality effect in learner-paced multimedia learning. *Procedia-Social and Behavioral Sciences, 30*, 1488-1493.

Scheiter, K., Schüler, A., Gerjets, P., Huk, T., & Hesse, F. W. (2014). Extending multimedia research: How do prerequisite knowledge and reading comprehension affect learning from text and pictures. *Computers in Human Behavior, 31*, 73-84.

Schmidt-Weigand, F., Kohnert, A., & Glowalla, U. (2010). A closer look at split visual attention in system-and self-paced instruction in multimedia learning. *Learning and instruction, 20*(2), 100-110.

Schüler, A., Scheiter, K., & Gerjets, P. (2013). Is spoken text always better? Investigating the modality and redundancy effect with longer text presentation. *Computers in Human Behavior, 29*(4), 1590-1601.

Segura, C., Pita, I., del Vado Vírseda, R., Saiz, A. I., & Soler, P. (2008). Interactive Learning of Data Structures and Algorithmic Schemes *Computational Science–ICCS 2008* (pp. 800-809): Springer.

Selby, C. C. (2015). *Relationships: computational thinking, pedagogy of programming, and Bloom's Taxonomy.* Paper presented at the Proceedings of the Workshop in Primary and Secondary Computing Education.

Seong, D. S. K. (2006). *Usability guidelines for designing mobile learning portals.* Paper presented at the Proceedings of the 3rd international conference on Mobile technology, applications & systems.

Seong, D. S. K., & Chee, C. F. (2006). Navigational patterns on usable mobile news portals. *Journal of Internet Technology, 7*(3), 239-245.

Seraj, M., & Wong, C. Y. (2014). Impacts of Different Mobile User Interfaces on Students' Satisfaction for Learning Dijkstra's Shortest Path Algorithm. *iJIM, 8*(4), 24-30.

Shaffer, C. A., Cooper, M., & Edwards, S. H. (2007). *Algorithm visualization: a report on the state of the field.* Paper presented at the ACM SIGCSE Bulletin.

Shaffer, C. A., Cooper, M. L., Alon, A. J. D., Akbar, M., Stewart, M., Ponce, S., & Edwards, S. H. (2010). Algorithm visualization: The state of the field. *ACM Transactions on Computing Education (TOCE), 10*(3), 9.

Shapiro, E. (2003). Behavioral observation of students in schools (BOSS). *Computer Software. San Antonio, TX: Psychological Corporation*.

Sharples, M., Arnedillo-Sánchez, I., Milrad, M., & Vavoula, G. (2009). *Mobile learning*: Springer.

Shitkova, M., Holler, J., Heide, T., Clever, N., & Becker, J. (2015). *Towards Usability Guidelines for Mobile Websites and Applications.* Paper presented at the Wirtschaftsinformatik.

Shneiderman, B. (2010). *Designing the user interface: strategies for effective human-computer interaction*: Pearson Education India.

Shneiderman, B., Plaisant, C., Cohen, M., & Jacobs, S. (2010). Designing the User Interface: Strategies for Effective Human-Computer Interaction, Addison-Wesley Publ. Co. *Reading, MA, USA*.

Shneiderman, B., Plaisant, C., Cohen, M., Jacobs, S., Elmqvist, N., & Diakopoulos, N. (2016). *Designing the user interface: strategies for effective human-computer interaction*: Pearson.

Simon, H. (1996). *The Sciences of Artificial* (3rd edn ed.). Cambridge, MA: MIT Press.

Simonák, S. (2013). Algorithm Visualization Using the VizAlgo Platform. *Acta Electrotechnica et Informatica, 13*(2), 54.

Siti Mahfuzah, S. (2011). *Conceptual Design Model of Computerized Personal-Decision AID (ComPDA).* Universiti Utara Malaysia.

Son, C., Park, S., & Kim, M. (2011). Linear Text vs. Non-Linear Hypertext in Handheld Computers: Effects on Declarative and Structural Knowledge, and Learner Motivation. *Journal of Interactive Learning Research, 22*(2), 241.

Sorva, J., Karavirta, V., & Malmi, L. (2013). A review of generic program visualization systems for introductory programming education. *ACM Transactions on Computing Education (TOCE), 13*(4), 15.

Spanjers, I. A., Gog, T., & Merriënboer, J. J. (2012). Segmentation of worked examples: Effects on cognitive load and learning. *Applied Cognitive Psychology, 26*(3), 352-358.

Spanjers, I. A., Van Gog, T., & van Merriënboer, J. J. (2010). A theoretical analysis of how segmentation of dynamic visualizations optimizes students' learning. *Educational Psychology Review, 22*(4), 411-423.

Stone, M. (2006). Color in information display. *Vis06*.

Stone, M. C. (2004). *Color in information display principles, perception, and models.* Paper presented at the ACM SIGGRAPH 2004 Course Notes.

Su, K.-W., Liu, C.-L., & Lee, C.-C. (2011). A mobile flight case learning system for ATC miscommunications. *Safety science, 49*(10), 1331-1339.

Sung, E., & Mayer, R. E. (2013). Online multimedia learning with mobile devices and desktop computers: An experimental test of Clark's methods-not-media hypothesis. *Computers in Human Behavior, 29*(3), 639-647.

Sutopo, H. (2011). Selection sorting algorithm visualization using flash. *The International Journal of Multimedia & Its Applications (IJMA), 3*(1), 22-35.

Sweller, J. (2011). Cognitive load theory. *The psychology of learning and motivation: Cognition in education, 55*, 37-76.

Syamsul Bahrin, Z. (2011). *Mobile game-based learning (mGBL) engineering model.* Universiti Utara Malaysia.

Terras, M. M., & Ramsay, J. (2012). The five central psychological challenges facing effective mobile learning. *British Journal of Educational Technology, 43*(5), 820-832.

Thompson, E., Luxton-Reilly, A., Whalley, J. L., Hu, M., & Robbins, P. (2008). *Bloom's taxonomy for CS assessment.* Paper presented at the Proceedings of the tenth conference on Australasian computing education-Volume 78.

Tongco, M. D. C. (2007). Purposive sampling as a tool for informant selection.

Traxler, J. (2007). Defining, Discussing and Evaluating Mobile Learning: The moving finger writes and having writ. *The International Review of Research in Open and Distributed Learning, 8*(2).

Traxler, J. (2012). Sustaining mobile learning and its institutions. *Refining Current Practices in Mobile and Blended Learning: New Applications*, 1-9.

Tudoreanu, M. E. (2003). *Designing effective program visualization tools for reducing user's cognitive effort.* Paper presented at the Proceedings of the 2003 ACM symposium on Software visualization.

Urquiza-Fuentes, J., & Velázquez-Iturbide, J. A. (2009a). Pedagogical effectiveness of engagement levels–a survey of successful experiences. *Electronic Notes in Theoretical Computer Science, 224*, 169-178.

Urquiza-Fuentes, J., & Velázquez-Iturbide, J. Á. (2007). An evaluation of the effortless approach to build algorithm animations with WinHIPE. *Electronic Notes in Theoretical Computer Science, 178*, 3-13.

Urquiza-Fuentes, J., & Velázquez-Iturbide, J. Á. (2009b). A survey of successful evaluations of program visualization and algorithm animation systems. *ACM Transactions on Computing Education (TOCE), 9*(2), 9.

Urquiza-Fuentes, J., & Velázquez-Iturbide, J. Á. (2013). Toward the effective use of educational program animations: The roles of student's engagement and topic complexity. *Computers & Education, 67*, 178-192.

Uzunboylu, H., & Ozdamli, F. (2011). Teacher perception for m-learning: scale development and teachers' perceptions. *Journal of Computer Assisted Learning, 27*(6), 544-556.

Valk, J.-H., Rashid, A. T., & Elder, L. (2010). Using mobile phones to improve educational outcomes: An analysis of evidence from Asia. *The International Review of Research in Open and Distributed Learning, 11*(1), 117-140.

Vrachnos, E., & Jimoyiannis, A. (2014). Design and evaluation of a web-based dynamic algorithm visualization environment for novices. *Procedia Computer Science, 27*, 229-239.

Wang, M., & Shen, R. (2012). Message design for mobile learning: Learning theories, human cognition and design principles. *British Journal of Educational Technology, 43*(4), 561-575.

Wang, S.-L., & Wu, C.-Y. (2011). Application of context-aware and personalized recommendation to implement an adaptive ubiquitous learning system. *Expert Systems with applications, 38*(9), 10831-10838.

Ware, C. (2012). *Information visualization: perception for design*: Elsevier.

Wen, G. Z. (2013). *The Algorithm Animation of Genetic Algorithm of Travelling Salesman Problem.* Paper presented at the Applied Mechanics and Materials.

Wilson, R., Shortreed, J., & Landoni, M. (2004). *A study into the usability of e-encyclopaedias.* Paper presented at the Proceedings of the 2004 ACM symposium on Applied Computing.

Wong, A., Leahy, W., Marcus, N., & Sweller, J. (2012). Cognitive load theory, the transient information effect and e-learning. *Learning and Instruction, 22*(6), 449-457.

Wong, L. Program Visualization: Effect Of Viewing Vs. Responding On Student Learning.

Wu, P.-H., Hwang, G.-J., Tsai, C.-C., Chen, Y.-C., & Huang, Y.-M. (2011). A pilot study on conducting mobile learning activities for clinical nursing courses based on the repertory grid approach. *Nurse Education Today, 31*(8), e8-e15.

Yap, B. W., & Sim, C. H. (2011). Comparisons of various types of normality tests. *Journal of Statistical Computation and Simulation, 81*(12), 2141-2155.

Zabel, T. W. (2010). Viability, Advantages and Design Methodologies of M-Learning Delivery. *Online Submission*.

Zhang, K. (2012). *Software Visualization: From Theory to Practice* (Vol. 734): Springer Science & Business Media.

Zollet, R., & Back, A. (2010). Website usability for internet banking.

APPENDIX A

Sample of Invitation Email to Experts

Expert Review for AVOMP Design Guidelines 4

Yahoo/Terkirim

ahmad Affandi <ahmad_affandi123@yahoo.com>

12 Nov 2017 jam 01.06

Kepada: jhy@ukm.edu.my, fadzilah@ukm.edu.my, tsmeriam@ukm.edu.my, ainuddin@um.edu.my, amir@um.edu.my dan 27 lainnya...

***Note: it is highly recommended to download and install the app, keyword: "inavomp" on google play to understand better about the initial prototype of this study (with case study: sorting algorithm),**

Assalamualaikum.. Selamat Sejahtera

Nama saya Ahmad Affandi Supli dan sekarang ini sedang mengikuti pengajian PhD pengkhususan Multimedia di Sekolah Teknologi Multimedia dan Komunikasi (SMMTC),Universiti Utara Malaysia (UUM). Dibawah penyeliaan Prof. Dr. Shuhada Shiratuddin. Sehubungan itu saya berminat dengan kepakaran Prof/Dr. dalam software engineering, multimedia learning, application and data structure algorithm. Saya percaya dengan kepakaran yang Prof./Dr. miliki ianya amat bersesuaian dengan bidang kajian saya.

Oleh itu disini saya berharap Prof/Dr. boleh menjadi pakar rujuk untuk menilai design guidelines yang saya bangunkan dinamakan sebagai "**Design Guidelines of Algorithm Visualization on Mobile Platform (AVOMP)**". Untuk makluman, AVOMP design guidelines adalah design guidelines reka bentuk bagi aplikasi multimedia yang direka khusus untuk belajar dan mengajar **data structure and algorithm (DSA)** subject.

Jika sekiranya Prof./Dr. bersetuju, saya akan menghantar borang persetujuan dan surat pelantikan rasmi daripada pihak UUM diikuti dengan lakaran design guidelines yang dicadangkan bersama-sama dengan instrumen (soal selidik). Saya percaya ia akan mengambil masa hanya kira-kira 20 hingga 30 minit untuk anda menilai design guidelines tersebut.

Persetujuan dari pihak Prof./Dr. amat-amat diharapkan dan segala kerjasama diucapkan berbanyak terima kasih.

Sekian..

Ahmad Affandi Supli (900946)
Sekolah Teknologi Multimedia dan Komunikasi (SMMTC)
Universiti Utara Malaysia (UUM)
0175019375

APPENDIX B

Official Appointment Letter by Dean

AWANG HAD SALLEH
GRADUATE SCHOOL OF ARTS AND SCIENCES
UUM College of Arts and Sciences
Universiti Utara Malaysia
06010 UUM SINTOK
KEDAH DARULAMAN
MALAYSIA

MUAFAKAT KEDAH

UUM/CAS/AHSGS/900946
29 October 2017

Aznoora Osman (Dr.)
Senior Lecturer
Computer Science Department
Faculty of Computer and Mathematical Sciences
UiTM Perlis Branch

Madam,

APPOINTMENT AS EXPERT REVIEWER FOR "ALGORITHM VISUALIZATION ON MOBILE PLATFORM" DESIGN GUIDELINES

With regard to the above, it is my pleasure to appoint you as an expert reviewer for the following PhD candidate:

Student Name:	**Ahmad Affandi Supli**
Matric No:	**900946**
School:	**School of Multimedia Technology and Communication, Universiti Utara Malaysia**
Research Title:	**Design Guidelines of Algorithm Visualization on Mobile Platform**
Supervisor:	**Prof. Dr. Norshuhada Shiratuddin**

Please give your expert opinion by completing the review form. Your cooperation, time and assistance are greatly appreciated.

Thank you.

Sincerely yours,

PROF. DR. NORSHUHADA SHIRATUDDIN
Dekan
Awang Had Salleh Graduate School of Arts and Sciences
Universiti Utara Malaysia

APPENDIX C

Pre-Test Instrument

Bubble Sort

1. (**analysis**) What is the maximum number of comparisons if there are 5 elements in array x?

A. 10
B. 2
C. 5
D. 25

2. (**understand**) Explain this code in plain English (what it does)

```
void bubblesort(Comparable[] A) {
  for (int i=0; i<A.length-1; i++) // Insert i'th record
    for (int j=1; j<A.length-i; j++)
      if (A[j-1].compareTo(A[j]) > 0)
        swap(A, j-1, j);
}
```

3. Sort this with bubble sort? 15,20,10,18,13 (List the output for each Pass) (**apply**)

Insertion Sorting

1. (**Knowledge**) What operation does the Insertion Sort use to move numbers from the unsorted section to the sorted section of the list?

A. Finding the minimum value
B. Swapping
C. Finding out a pivot value
D. None of the above

2. (**Analysis**) Consider the following lists of partially sorted numbers. The double bars represent the sort marker. How many comparisons and swaps are needed to sort the next number. [**1 3 4 8 9 || 5 2**]

- A. 2 comparisons, 3 swaps
- B. 3 comparisons, 2 swaps
- C. 4 comparisons, 3 swaps
- D. 3 comparisons, 4 swaps

3. (**understand**) Explain this code in plain English (what it does)

```
void inssort(Comparable[] A) {
  for (int i=1; i<A.length; i++) // Insert i'th record
    for (int j=i; (j>0) && (A[j].compareTo(A[j-1]) < 0); j--)
      swap(A, j, j-1);
}
```

4. (**apply**)Sort this with Insertion sort? 15,20,10,18,13 (List the output for each Pass)

Selection Sort

1. (**knowledge**) Which one of the following is the first step in a selection sort algorithm (based on question number 3)?

A. The minimum value in the list is found

B. The maximum value in the list is found

C. Adjacent elements are swapped

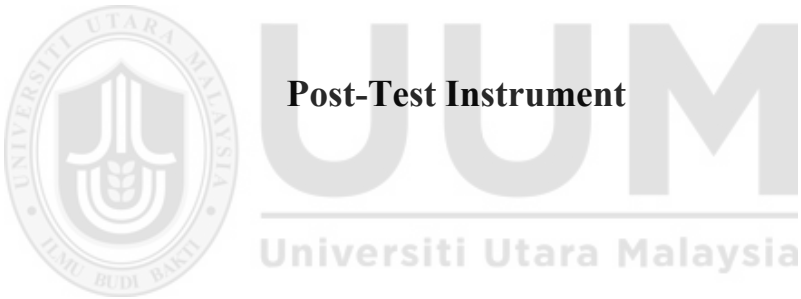
2. (**analysis**) How many passes/scans will go through a list of 10 elements?
a. A. 11
b. B. 9
c. C. 20
d. D. 25

3. (**understand**) Explain this code in plain English (what it does)

```
void selsort(Comparable[] A) {
  for (int i=0; i<A.length-1; i++) {
    int bigindex = 0;
    for (int j=1; j<A.length-i; j++)
      if (A[j].compareTo(A[bigindex])
        bigindex = j;
    swap(A, bigindex, A.length-i-1);
  }
}
```

4. (**apply**)Sort this with Selection sort 15,20,10,18,13 (List the output for each Pass)?

APPENDIX D



Post-Test Instrument

Bubble Sorting

1. (**analysis**) What is the max. number of comparisons that can take place when a bubble sort is implemented? Assume there are n elements in the array?

A. (1/2)(n-1)
B. (1/2)n(n-1)
C. (1/4)n(n-1)
D. None of the above

2. (**understand**) Explain this code in plain English (what it does)

```
void bubblesort(Comparable[] A) {
  for (int i=0; i<A.length-1; i++) // Insert i'th record
    for (int j=1; j<A.length-i; j++)
      if (A[j-1].compareTo(A[j]) > 0)
        swap(A, j-1, j);
}
```

3. Sort this with bubble sort? 18,98,70,11,25 (List the output for each Pass) (**apply**)

Insertion Sorting

1. (**Knowledge**) What is the first operation of Insertion Sort in the nested for loop?

A. Swapping
B. Finding the minimum value
C. Finding out a pivot value
D. None of the above

2. (**analysis**) Consider the following lists of partially sorted numbers. The double bars represent the sort marker. How many comparisons and swaps are needed to sort the next number. [**1 3 4 5 8 9 || 2**]

a. A. 5 comparisons, 4 swaps
b. B. 4 comparisons, 5 swaps
c. C. 6 comparisons, 5 swaps
d. D. 5 comparisons, 6 swaps

3. (**understand**) Explain this code in plain English (what it does)

```
void inssort(Comparable[] A) {
  for (int i=1; i<A.length; i++) // Insert i'th record
    for (int j=i; (j>0) && (A[j].compareTo(A[j-1]) < 0); j--)
      swap(A, j, j-1);
}
```

4. (**apply**) Sort this with Insertion sort? 18,98,70,11,25 (List the output for each Pass)

Selection Sorting

1. (**knowledge**) In a selection sort structure, there is/are?
    a. A. Two separate for loops
    b. B. Three for loops, all separate
    c. C. Two for loops, one nested in the other
    d. D. A for loop nested inside a while loop

2. (**analysis**) How many passes (or "scans") will there be through a list being sorted using a selection sort?

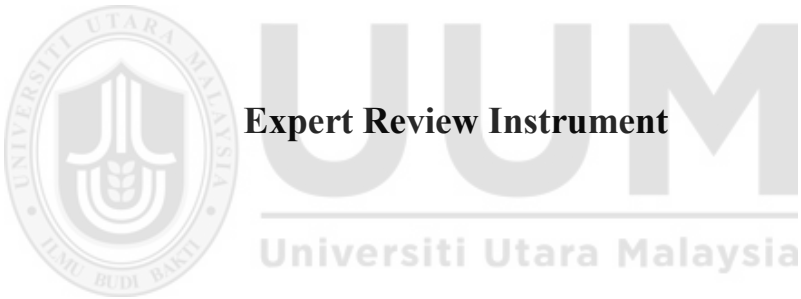
    e. A. Array_size*2
    f. B. Array_size+1
    g. C. Array_size-1
    h. D. None of the above

3. (**understand**) Explain this code in plain English (what it does)

```
void selsort(Comparable[] A) {
  for (int i=0; i<A.length-1; i++) {
    int bigindex = 0;
    for (int j=1; j<A.length-i; j++)
      if (A[j].compareTo(A[bigindex])
        bigindex = j;
    swap(A, bigindex, A.length-i-1);
  }
}
```

4. (**apply**) Sort this with Selection sort? 18,98,70,11,25 (List the output for each Pass)

APPENDIX E



Expert Review Instrument

***Note: the initial prototype of this study can be seen in google play, keyword: "inavomp"**

INSTRUMENTS DEVELOPMENT

AVOMP Design Guidelines evaluation will involve 2 types of instrument. This phase is conducted to achieve 3rd and 4th objectives of this study:

1. To identify the suitable recommendations for AVOMP Design Guidelines.
2. To construct design guidelines of algorithm visualization on mobile platform (AVOMP).
3. To validate AVOMP design guidelines in term of "applicability" through expert review.
4. To measure students' effectiveness of the AVOMP design guidelines through prototype.

Instrument	Purpose	Participant
1. Expert Review Form	To evaluate the **validity** of the AVOMP Design Guidelines in term of **"applicability".**	Experts (practitioners & academicians)
2. Sorting Test	To measure students' effectiveness. (Results learning performance)	IT Students (who enrolled the Data Structure and Algorithm (DSA) subject)

INSTRUMENT FOR EXPERT REVIEW:

DESIGN GUIDELINES OF ALGORITHM VISUALIZATION ON MOBILE PLATFORM (AVOMP).

Dear Prof/Dr./Sir/Mdm

EXPERT REVIEW ON DESIGN GUIDELINES OF ALGORITHM VISUALIZATION ON MOBILE PLATFORM.

My name is Ahmad Affandi Supli and currently doing PHD study in multimedia of studies at University Utara Malaysia (UUM). I am delighted to inform that you have been selected to participate in this research on reason as follow;

- Your qualifications is either in HCI or CS or SE related areas and/or.
- You have been studying/researching/teaching HCI/SE/CS for at least five years.
- You have been teaching one of the following subjects: data structure and analysis (DSA), algorithm, programming, for at least 5 years

My PhD research propose the "**Design Guidelines of Algorithm Visualization on Mobile Platform (AVOMP) "**. These design guidelines are proposed with the aim to assist developers/designers/lecturers by understanding what kind of knowledge they may need in order to achieve a successful design step in developing algorithm visualization applications. Therefore, the objective of this expert review is to:

1. Evaluate the relevant of the proposed recommendations/guidelines
2. Identify and combine duplicate guidelines
3. Identify and resolve guidelines that conflicted with each other
4. Reword unclear guidelines.

The information given will be treated as confidential and only be used as a research purposes which will be anonymously reported in academic publications.

Please feel free to contact me by email (ahmad_affandi123@yahoo.com) for any queries or my supervisor email (shuhada@uum.edu.my).

Your kind cooperation and assistance are highly appreciated.

Instruction:

Please go through the figure of AVOMP design guidelines. Based on your expertise, please provide feedback and suggestion in a space provided. Please refer to **Appendix A** for detail explanations of each terminology.

EXPERT REVIEW FORM

EXPERT REVIEW DETAILS

Name* : _____

Age : _____

Gender : **Male** ☐ **Female** ☐

Organization/ Instituition/ : _____

Experience* : _____ **[years]**

**Compulsory*

ITEMS FOR REVIEW

Based on the proposed AVOMP Design Guidelines (as depicted in the given hand-out), please tick (√) your choice.

Guidelines (G)	Needs very detail explanations	Need some explanations	Is easy to understand
G1			
G2			
G3			
G4			
G5			
G6			
G7			
G8			
G9			
G10			
G11			
G12			
G13			
G14			
G15			
G16			
G17			

***Guideline (G).**

please tick (√) your choice.
Likert importance scale with the anchors set at **'Important (1)' to 'Very Important (5)**.'

Guidelines (G)	1	2	3	4	5
G1					
G2					
G3					
G4					
G5					
G6					
G7					
G8					
G9					
G10					
G11					
G12					
G13					
G14					
G15					
G16					
G17					

The language and terms in each guideline

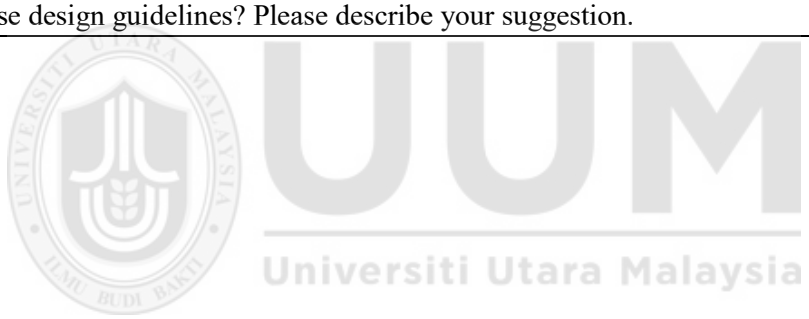
Likert scale of easy to understand with the anchors set at **'Strongly disagree(1)' to 'Strongly agree(5)**.'

Guidelines (G)	1	2	3	4	5
G1					
G2					
G3					
G4					
G5					
G6					
G7					
G8					
G9					
G10					
G11					
G12					
G13					
G14					

G15					
G16					
G17					

1	The design guidelines for representing the problem are relevant.	Yes		No	
2	The design guidelines for representing the solution are relevant.	Yes		No	
3	The connections and flows of all the guidelines are logical	Yes		No	
4	The design guidelines are applicable to the development of algorithm visualization on mobile platform.	Yes		No	
5	Overall, the design guidelines are readable.	Yes		No	
6	Overall, the design guidelines are applicable.	Yes		No	

10. Would you suggest to add any relevant guidelines or additional recommendations in these design guidelines? Please describe your suggestion.



11. Would you suggest to remove any explanation or guideline? Please describe your suggestion.

12. Would you suggest any updates or improvements related to the AVOMP design guidelines in term of combining duplicate guidelines, reword unclear guidelines, implementation, and resolve guidelines that conflicted with each other? Please explain your suggestion?

13. Could the design guidelines be made more applicable in a prototype development? How?

14. Please write any further comments below: