Promoting critical thinking dispositions in children and adolescents through Human-Robot Interaction with Socially Assistive Robots

Dimitris Pnevmatikos
Department of Primary Education
University of Western Macedonia
Florina, Greece
dpnevmat@uowm.gr

Panagiota Christodoulou
Department of Primary Education
University of Western Macedonia
Florina, Greece
pchristodoulou@uowm.gr

Nikolaos Fachantidis
Department of Educational and Social Policy
University of Macedonia
Thessaloniki, Greece
nfachantidis@uom.edu.gr

***Abstract*— The current paper describes a preliminary concept according to which robotic tutors are employed for promoting critical thinking dispositions in children and adolescents between the age of 10 and 18. Although critical thinking is among the most essential 21st-century skills, still is a challenging task for educators to achieve. However, robotic tutors motivate users and facilitate knowledge gains and behavioral changes due to their personalized behavior towards users' needs. Still, they have not been employed for promoting critical thinking. Here we present an experimental set-up according to which a robotic tutor introduces stimuli to the learner and engages in discussion resulting to evidence-based inquiry. The robot employs questions, hints, and gestures through the discussion for the promotion of critical thinking dispositions. A holistic approach on critical thinking instruction is employed, yet without explicitly teaching critical thinking skills. Implications are discussed concerning the evaluation and measurement of critical thinking dispositions.**

Keywords—critical thinking, critical thinking dispositions, Human-Robot Interaction, Socially Assistive Robots

I. Introduction

As the world has transformed from an industrial society to a knowledge-based society, the necessary skills for the workforce have evolved. These set of skills, described as the 21st-century skills, have been characterized as essential for education and future workforce in order for future citizens to function effectively in the society [1]. Particularly for school, 21st-century skills are essential due to the challenges the younger generation will encounter in the new global economy with the emergence of sophisticated Information and Technologies Communication (ICTs) [2]. Therefore, a need to shift from knowledge acquisition, which was important for the 20th-century education, to the development of skills and competencies has emerged [2]. Corresponding to this need, many academics and policymakers have suggested reforms in curricula and education standards aiming to include 21st-century skills in everyday teaching practices [3, 4]. Critical Thinking (CT) has been highlighted as one of the 21st-century skills and essential education goal for future citizens since it is a process aiming to produce reasonable and reflective decisions on what to believe or do [5]. In this way, CT allows individuals to make autonomous decisions and to question beliefs when these do not result in solid evidence [6, 7].

Although CT has been singled out as one of the most vital 21st-century skills [6], teaching for CT is not an easy task for teachers, instructors, or academics to achieve. First, teaching for CT is a challenging task, due to the disagreements on CT definitions and its complex nature. This results in another debate, namely whether CT is domain specific or domain general. In the first case, CT can be taught in domain-specific subject matters, while in the latter case CT can be generalized across domains and taught generically [8]. Moreover, such epistemological presuppositions have consequences on the strategies employed for CT instruction. Halpern [6] suggests the need for the explicit teaching of CT because there is little evidence suggesting that CT merely develops because of instruction in a discipline. Additionally, deliberate and repeated practice is required for CT to be transferred in different contexts [9]. Finally, CT is challenging to master through education and training because it is a higher-order-skill; built-up by lower-order thinking skills (e.g., ability to recall or understand information), which first need to be developed [10, 11]. Therefore, it is a challenge for the educators to develop innovative interventions that will promote critical thinking skills in individuals. In the current paper, we argue that the development of a holistic approach that will integrate Socially Assistive Robots (SAR) as an integral part of the explicit instruction will be a useful tool for promoting CT in children and adolescents (i.e., between 10 and 18 years old).

SARs have been employed widely in the field of education due to their potential to improve teaching and learning [12]. Until recently, robotics have been employed more as a lab tool for educational activities that supports instruction of STEM-related subjects, as well as skills development related to the problem-solving and scientific inquiry. Nevertheless, with the advent of SAR, the role of the robots employed in education has slightly shifted from that of a tool to a more active peer or tutor [13]. Beyond the robot's capabilities of moving and acting autonomously, the robot's physical embodiment and the abilities to communicate and interact with users in a social manner (e.g., use speech and gestures to provide feedback) has proved to be beneficial for motivating and engaging users in Human-Robot Interaction (HRI) [14]. SAR's successes in

HORIZON 2020 Research and Innovation Program-Grant Agreement No 709515

XXX-X-XXXX-XXXX-X/XX/$XX.00 ©20XX IEEE

motivating humans rely on the inherent human tendency to engage with lifelike social behavior, [15] as well as to their ability to persuade them in committing to a particular behavior or activity [16]. Literature findings suggest that manipulation of the robot's social cues (i.e., physical, psychological, language, social dynamics, and social roles) affect the robot's persuasiveness and therefore influence HRI [17]. Moreover, the responsiveness SAR exhibit towards humans' needs is inherent in the formation of emotional bonds [18]. Furthermore, research has shown that people behave more socially towards a robot with personalized behavior and can even alter their own behavior [19].

In particular, in this work-in progress-paper, we will present a preliminary idea of how the implementation of SAR could take place in educational context aiming at promoting CT in children and adolescents between the age of 10 and 18 years old .

II. Promoting Critical Thinking Through Education

A. *Conceptualization of critical thinking*

CT is a broad term with many interpretations and has been extensively discussed over the years considering different academic disciplines. In this study, we adopt the concept as grounded in a Delphi research study [20], covering various study areas and suggesting that both cognitive (i.e., Critical Thinking Skills-CTS) and affective aspects (i.e., Critical Thinking Dispositions-CTD) are essential for CT. According to the results of this study CT is defined as a process of purposeful, self-regulatory judgment, which results in two different procedures; (i) the interpretation, analysis, evaluation and inference, and (ii) the explanation of the evidential, conceptual, methodological or contextual considerations upon which the original judgment was based. Additionally, the definition deepens further, indicating the virtues or qualities that a critical thinker has such as inquisitiveness, concern to become or remain well informed, trust in the process of reasoning, open-mindedness, fair-mindedness in appraising reasoning, honesty in facing one's bias, stereotypes and prejudices, prudence in making judgments, willingness to reconsider one's judgments [20]. In addition, critical thinkers confront questions or problems with, clarity in stating questions or concerns, orderliness in working with complexity, diligence in seeking information, reasonableness in selecting and applying criteria, care in focusing at the issue at hand, persistence when difficulties are encountered and precision to the degree allowed by the subject under investigation [20]. Accordingly, six core cognitive skills are indicated when it comes to CT; (i) interpretation, (ii) analysis, (iii) inference, (iv) evaluation, (v) explanation and (vi) self-regulation.

Building on the findings of the Delphi study Facione stated that CTS alone are a necessary but not a sufficient condition for the development of CT. Therefore, it made explicit that a critical thinker displays certain dispositions, namely (i) truth-seeking, (ii) open-mindedness, (iii) analyticity, (iv) systematicity, (v) self-confidence, (vi) inquisitiveness, (vii) maturity of judgement, when involved in CT processes [21, 22]. Dispositions are considered as the consistent internal motivation to engage with problems and make decisions by thinking critically [23]. Truth-seeking is perceived as the eagerness to seek the best knowledge in a given context, being courageous about asking questions, objective and honest about pursuing the inquiry. The CTD of being open-minded is the process of being tolerant of divergent views and sensitive to personal bias. Analyticity is a CTD for applying reasoning and using the information to solve problems, anticipating potential conceptual or practical difficulties and be ready to intervene, when needed. Systematicity is the CTD where one organizes his thinking and actions in problem-solving and decision-making procedures and focuses on being diligent in the inquiry. Another CTD is self-confidence, which refers to trusting one's reasoned judgments and be inclined to lead others in problem-solving. Moreover, intellectual curiosity and desire to learn is considered the CTD of inquisitiveness. Finally, the maturity of judgment is related to particular context-based approaches and considerations of different opinions and ethical norms. Giancarlo, Blohm, and Urdan [24] highlight the importance of CTD indicating that it is insignificant to learn a CTS if when individuals are in need of that skill, they fail to exercise what they have learned. In addition, Ku and Ho [25] suggest that CTD affect thinking in various ways, such as providing to the individual the impetus to engage in deep thinking and reasoning processes. This is also justified by recent cognitive models of decision making (i.e., Dual Process Theory) proposing that the thinking process is facilitated by two systems of thinking (System 1 and System 2), which act in parallel while processing evidence during decision-making procedures [26, 27]. System 1 is more intuitive, reactive, and holistic and relies on heuristics. Thus, it is employed in situations that time is short and an immediate response is required. System 2 is useful for judgments related to unfamiliar situations, it allows the process of concepts, planning, considering options, review, revise and appreciate well-articulated evidence. If a person is critically disposed towards thinking and reasoning processes, namely values analytical thinking, truth-seeking, and open-mindedness, then it is more likely to activate the System 2 and engage in a more in-depth process of thinking which will result to better decision making [28]. Even in the case that the System 2 endorses an intuitive judgment, an individual who is critically disposed of will not be satisfied with the judgment until all possibilities have been checked and a satisfying solution has been reached by overriding the original intuitive judgment [29, 30].

B. *Instruction for Critical Thinking*

As presented earlier the on-going debate regarding the CT definition and its nature (i.e., domain-general or domain specific) has implications for the instruction of CT and its integration in the curricula. Ennis [5] suggested four different teaching approaches for CT, namely *general, infusion, immersion and mixed* approach. In the general approach, CT is taught separately from the content of a specific subject matter. In the case of infusion, instructors attempt to introduce CT in standard subject matters by making the general principles of CT explicit for students. Although immersion approach integrates CT in a specific subject matter, CT principles are not introduced directly to students. Finally, the mixed approach combines the general with either the infusion or the immersion approach. In their meta-analysis, Abrami et al. [31] identified the mixed approach as one with the most favorable effects for learners.

Apart from the approach, variations appear concerning the instruction methodologies of CT. Among the most common methods employed for CT are problem-based learning, inquiry teaching, computer-based instruction, serious games, concept mapping and higher-order questioning. Nevertheless, research in instruction for CT aiming to children and adolescents is more limited. For instance, collaborative group activities along with instructor guided questions and group debates have been utilized and proved to be more effective for secondary school students in promoting CTD than whole class instruction [32]. Similarly, primary education students' critical ability was significantly enhanced when engaged in collaborative-problem solving activities [33]. Moreover, a mixed approach towards CT employing inquiry-based teaching along with explicit instruction for enhancement of students' awareness of ideas, beliefs, and thinking processes proved beneficial for fostering students' CTD [34]. Finally, as the meta-analysis of [31] indicated the most effective techniques for CT enhancement are dialogue related type of strategies (e.g., questioning, peer discussion, debate) and authentic or anchored instruction (e.g., problem-solving techniques, simulations, case studies and role-plays).

Another issue related with CT instruction is the fact that the majority of studies emphasize more on the instruction of CTS underrating both the importance of CTD and the fact that CTS are developed after considerable practice and effort [6]. The undervaluing of CTD is a significant concern demonstrating that educators do not pay enough attention to their teaching and modeling in the class [35]. Also, Facione [21] argued that in the case that educational programs focus only on CTS and neglect the consistent internal motivation to use those skills (that is the dispositions), then education aiming at CT will fail. Acknowledging the need for instruction on CTD [36] proposed a four steps model. Firstly, the instructor should train learners so that they develop the dispositions to engage in CT, secondly teach them explicitly the critical thinking skills, thirdly design learning activities in ways that increase the probability of transferring these skills to other contexts and finally make metacognitive monitoring explicit. The literature review findings highlight that CTS and CTD cannot be distinguished during instruction. When one is motivated to think critically, he also engages in CT process and therefore employs CTS. However, the issue is whether an instruction on CTS will be explicit or not so that the individual is aware of the skills he employs during thinking processes.

III. SOCIALLY ASSISTIVE ROBOTS IN EDUCATION

Socially Assistive Robots is a field where robots are employed aiming to provide motivational, engaging, social, personalized, and long-term support to people in different areas such as elderly care [e.g., 37] and (special) education [e.g., 38, 13]. The robot develops a close and effective, nonphysical, social interaction with the human to provide assistance [39] and support.

Despite the increasing number of initiatives exploring the use of SAR as agents in educational contexts, there are not yet any studies reporting results on promoting CT with SAR. Nevertheless, the latter are employed extensively for motivating behavior changes or engagement in learning activities. For instance, a robot that engages in verbal and non-verbal communication motivated primary school children to change their lifestyles and eating habits [40]. To illustrate further, elementary schoolchildren who interacted with a robotic partner, which they could teach handwriting were found to be more motivated to engage them in the activity. Also, metacognitive aspects were stimulated by the interaction with the robot as children had to reflect and consider why the robot failed to learn writing [41]. Moreover, when children played an interactive story-telling game with a physically embodied, affect-aware robot tutor in comparison to a tablet, children generated stronger engagement and enjoyment during the interaction [42]. The common denominator in all these cases responsible for increasing motivation in users and achieve behavior changes and learning gains were assumed the robot's social capabilities.

One of the social capabilities of the robot with particular interest for the current study is the personalization of the robotic tutor behavior towards the users' needs. Its importance is highlighted by the fact that it can lead to a motivated user who eventually achieves learning gains and behavioral changes. This can be interpreted by the Self-Determination Theory (SDT) proposed by Ryan and Deci [e.g., 43]. According to SDT, an individual becomes internally motivated to engage in a task when his basic psychological needs (i.e., the need for self-competence, need for autonomy, and need for relatedness) are satisfied. With a robot's personalized behavior, which can be achieved with various ways such as increase of the friendliness or social presence, the customization of the robot's appearance and personality, the task preferences or the feedback provided to the user [44, 45], this is more likely to be achieved. For instance, the need for self-competence could be facilitated in the case that the robot personalizes the level of a task's difficulty, according to the user's level of performance. In this case, the individual is more likely to feel competent enough to deal with a particular task that is not, more demanding than the person perceives. Latter on recent research findings will be presented to support this assertion.

Gordon & Breazeal [45] employed the continuous and efficient assessment of the student's skills, which led to a personalized behavior of the robot towards elementary school children. The robot was presented as a peer that wished to learn reading. Children who interacted with a personalized robotic tutor in comparison to random tutoring optimized their information gain and revealed substantial engagement in the task. In another study with primary school children, a humanoid robot- tablet game-child interaction was employed to challenge pupils' learning performance and increase their motivation. The robot adapted the level of assignments within the game to child's performance. Results revealed that children were more motivated to be engaged with the robot that provided them a personalized task in comparison to the robot that did not provide a similar behavior [46].

Hence higher order cognitive skills, such as self-regulation, can be observed more in primary school children when the robotic tutor adaptively scaffolds self-regulated behavior [47, 48]. This scaffolding took place through an open learner model, where pupils engaged in a geography task and were provided domain tutoring information by the robot, namely introduction to the task, its tools and performing of idle motions. Additionally, according to the children's answers, the robot engaged in verbal and nonverbal feedback (control case) as well as in feedback that scaffolded self-regulation. This feedback was initiated by different triggers related to the users'actions in the task (e.g., not mastering an activity, timeout, inappropriate tool selection). According to the authors, the robot by providing self-regulated feedback, facilitated pupils reflection on their current abilities, strengths, and weaknesses so that they could eventually re-organize their learning through the appropriate selection of tools or activities within the task.

IV. PROMOTING CRITICAL THINKING DISPOSITIONS WITH SOCIALLY ASSISTIVE ROBOTS: A PROPOSAL

The current study presents a preliminary concept on how CTD could be promoted through the employment of SAR, and it is part of an ongoing project (2016-2019) called STIMEY- Science, Technology, Innovation, Mathematics, Engineering for the Young, funded by the European program Horizon 2020 [http://promostimey.uca.es/]. With respect to instruction on CT we will employ Halpern's CT model, but since the emphasis is not on the CTS rather on the CTD, the first will not be explicitly taught as suggested in the model. In addition, the infusion approach as suggested by Ennis [5] will be employed along with evidence-based inquiry method.

A SAR will be developed within the context of the STIMEY project, which will operate through a detachable Android phone [49]. The robot will be personalized in terms of appearance and personality since the user could modify it according to his/her preferences (e.g., change the colors, dress it appropriately, and choose a voice according to a specific gender). In addition personalized behavior will be achieved through feedback provided to the user as well as personalized responses according to user's progress in a task. Among other functions, the robotic tutor will motivate participants to employ CTD when engaged in inquiry-process through personalized responses and feedback.

A. The experimental set-up

The robot will be positioned on user's table, opposite the user in order for it to be at a similar height to the learner. The robot will initially greet the user and will introduce a stimulus to initiate a discussion and engage the user in the evidence-based inquiry. This stimulus will be a short quote from an internet article, regarding a scientific phenomenon, e.g., "Seasonal changes happen because of the distance the earth has from the sun". The authors will develop the material and the selection of quotes so that they will depict learners' misconceptions on different scientific phenomena. In addition, misconceptions will vary depending on the child's age, since some of them can be surpassed during adolescence. After presenting the stimuli, the robot asks the user to consider it regarding its truthfulness. Fig. 1. depicts a potential dialogue between the child and the robot regarding the original stimulus. With the first question, the CTD of truthfulness is triggered. Then the robot prompts the child to engage in an evidence-based inquiry. Here it is apparent that the user will be engaged in processes that involve CTS. Nevertheless, no direct instruction on CTS will be initiated. Additionally, the user will be able to use the smartphone embodied on the robot for the internet search. During this inquiry process, the robot will remain idle (e.g., smile, change colors).

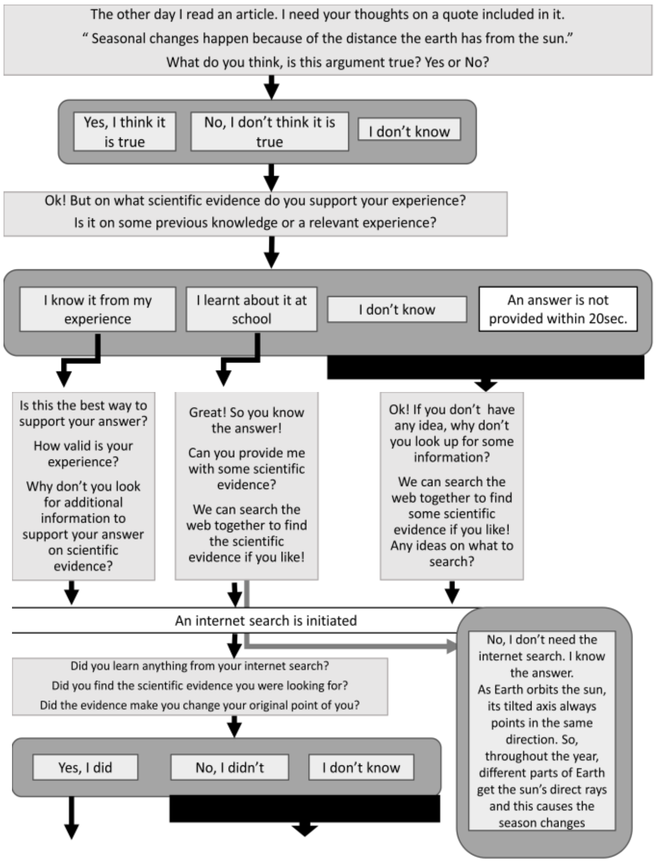

Fig. 1: The tree diagram depicting the interaction between the child and the robot; light grey is for the robot's responses, dark grey for the users' responses and white for triggers.

Additionally, if the user persists on looking for evidence, the robot will provide positive feedback encouraging him to continue. In the case that the search is irrelevant to the subject, the robot will ask the user to try alternative entries and stay more focused. In addition, some robot's gestures and noises will be employed depending on the response (i.e., positive or sympathetic response). By the end of the interaction between the robot and the user, the first one will provide a reflection on different processes the child was involved in making explicit the CTD involved in each stage, e.g., "I think it really helped you that you sought for the truth of the original argument. Also, you found a lot of evidence that made your opinion more solid than before; you should do it more often!" To avoid repetition of the same questions concerning each disposition different set of phrases will be employed. Table I presents some indicative and alternative questions for the interaction.

Since CT cannot happen overnight, a longitudinal approach would be essential to investigate at least whether a long-term change in behavior is achieved. In that case, after a few sessions between the robot and the child, the interaction would differentiate minimizing the scaffold on behalf of the robot. For example, if a child systematically uses evidence to support an argument, the robot could differentiate the answer, and instead of asking the child to provide some evidence, it could suggest, “Usually you judge a statement according to scientific evidence. I hope you have found evidence for this …” Gradually the robot instead of making questions, it would ask the user to describe the procedures he is involved in while evaluating a statement (e.g., What is your first step in evaluating an argument?). Finally, if the user mastered the activity, a congratulation response would be triggered while some hints could be provided in the case that the user did not engage appropriately with CTD.

Table I. Robot responses related to CT dispositions

CT Dispositions	***Robot response***
Truth-seeking	-Is this argument true? -Did you question any of your beliefs? -Is this the best knowledge on which you can build your argument? -Did you find information on both sides of the argument? -Are there any consequences related to your argument?
Open-mindedness	-Did you respect different opinions on your argument? -Did you appreciate or laugh at others’ arguments?
Analyticity	-Did you think the outcomes of your decisions? -Did you use evidence when tried to resolve the problem? -Did you think in advance any difficulties related to your argument?
Systematicity	-Did you organize your approach to solve an issue or problem? -Which steps did you follow to search for evidence -Did you try to solve a problem without thinking in advance how to solve it?
Self-confidence	-Did you have confidence when you tried to solve a challenging problem? -Did you work on the problem or did you asked for help?
Inquisitiveness	-Did you learn something new? -Was this new information/evidence important for you? -Did you engage in an activity because it is useful for you?
Maturity of judgment	-Did you reconsider your argument according to other opinions? -Did you change your original belief according to the scientific evidence? -Were you willing to reconsider your argument at all?

V. Concluding Remarks

We have presented a preliminary concept on how SAR could promote CTD through an introduction of stimuli that initiate an evidence-based inquiry for children and adolescents. The robotic tutor will motivate participants in employing CTD through personalized responses and feedback.

Robotic tutors are chosen in the current study to address the issue of individualized support that most schools lack (i.e., primary and secondary level) [50]. In addition, they are employed because they can support skills development and long-term behavior change [14]. Moreover, research findings suggest that robotic tutors are effective for increasing users’ learning outcomes and engagement [46]. Still, although short-term studies (e.g., a single session) are usual, long-term explorations (e.g., over weeks or months) are relatively rare [51]. Future work will implement the current concept in a longitudinal study, where students and adolescents between the age of 10 and 18 will interact with the robot in 8 sessions, one per week over a period of 2 months. Each session will be limited up to 20 minutes of interaction. Additionally, pre, post, and delayed post measurements will be conducted to evaluate the effects of the intervention.

Still, challenges related to the evaluation and measurement of CT are evident. Reliability and validity issues prevent the widespread use of different scales, inventories, and standardized tests developed for measuring CTS and CTD [52]. Another barrier in CT measurement is its nature consisting of both skills and dispositions. This means that an individual who is disposed to think critically or who has developed CTS only is not a priori, a critical thinker. Therefore, here we propose a qualitative measurement of CTD with a self-evaluation task. Learners will be engaged in the process of describing the CTD they are engaged in during the activity. This measurement presupposes that learners at least know which are the CTD. Additionally, a similar task like the one of the experimental condition with a different context will be provided to learners. In this way, transferability of motivation to engage in CT-namely CTD will be evaluated

Finally, development of CT is not an easy process to achieve. A systematic approach addressing both CTS and CTD is required. Thus, instruction for CT should be initiated from a small age and be targeted as a lifetime goal. Although the current concept lacks the explicit instruction of CTS, it does not omit CTS. Hence, by employing the advantages of robotic tutors as highlighted in the research field, we aim at a long-term behavior change.

VI. Acknowledgements

This project has received funding from the European Union’s Horizon 2020 Research and Innovation Programme under Grant Agreement Nº 709515.

References

1. P. Griffin, B. McGaw and E. Care, Eds., *Assessment and teaching of 21st century skills*. Dordrecht, The Netherlands: Springer, 2012.
2. C. Dede, “Comparing frameworks for 21st-century skills,” in 21st-century skills: Rethinking how students learn, J. Bellanca and R. Brandt, Eds. Solution Tree Press, 2010, pp. 51-76.
3. K. Ananiadou and M. Claro, “21st Century Skills and Competences for New Millennium Learners in OECD Countries,” OECD Education Working Papers, No. 41,

OECD Publishing, 2009. http://dx.doi.org/10.1787/218525261154
4. National Research Council, “Education for life and work: Developing transferable knowledge and skills in the 21st century, ” Ottawa-Ontario, USA: National Academies Press, 2013.
5. R. H. Ennis, “Critical thinking and subject specificity: Clarification and needed research,” Educational Researcher, vol. 18, pp. 4–10, April 1989.
6. D. F. Halpern, Thought and Knowledge, 5th ed. New York: Psychology Press, 2014.
7. J. W. Mulnix, “Thinking critically about critical thinking,” Educational Philosophy and Theory, vol. 44, pp. 464–479, July 2012.
8. E. R. Lai, “Critical thinking: A literature review,” Pearson's Research Reports, vol. 6, pp. 40-41, June 2011.
9. T. V. Gelder, M. Bissett and G. Cumming, “Cultivating expertise in informal reasoning,” Canadian Journal of Experimental Psychology, vol. 58, pp. 142–152, June 2004.
10. T. V. Gelder, “Teaching critical thinking: Some lessons from cognitive science,” College Teaching, vol. 53, pp. 41-48, August 2005.
11. C. P. Dwyer, M. J. Hogan and I. Stewart, “An integrated critical thinking framework for the 21st century,” Thinking Skills and Creativity, vol. 12, pp. 43-52, June 2014.
12. F. B. V. Benitti, “Exploring the educational potential of robotics in schools: A systematic review,” Computers & Education, vol. 58, 978-988, April 2012.
13. O. Mubin, C. J. Stevens, S. Shahid, A. Al Mahmud and J. J. Dong, “A review of the applicability of robots in education,” Journal of Technology in Education and Learning, vol. 1, pp. 209-0015, 2013.
14. A. Tapus, M. J. Mataric and B. Scassellati, “Socially assistive robotics [grand challenges of robotics,” IEEE Robotics & Automation Magazine, vol. 14, pp. 35-42, March 2007.
15. M. Matarić, “Socially assistive robotics: human-robot interaction methods for creating robots that care” in Proceedings of the 2014 ACM/IEEE international conference on human-robot interaction, 2014, pp. 333-333.
16. V. Chidambaram, Y. H. Chiang and B. Mutlu, “Designing persuasive robots: how robots might persuade people using vocal and nonverbal cues,” in Proceedings of the seventh annual ACM/IEEE international conference on human-robot interaction, 2012, pp. 293-300.
17. B. J. Fogg, “Persuasive technology: using computers to change what we think and do,” Ubiquity, pp. 89-120, December 2002.
18. G. E. Birnbaum, M., Mizrahi, G. Hoffman, H. T, Reis, E. J. Finkel and O. Sass, “What robots can teach us about intimacy: The reassuring effects of robot responsiveness to human disclosure,” Computers in Human Behavior, vol. 63, pp. 416-423, October 2016.
19. D. Leyzberg, S. Spaulding and B. Scassellati, “Personalizing robot tutors to individuals’ learning differences,” in International conference on human–robot interaction, 2014, pp 423–430.
20. P. Facione, Critical thinking: A statement of expert consensus for purposes of educational assessment and instruction: The Delphi Report. California: California Academic Press, 1990.
21. P. A. Facione, “The disposition toward critical thinking: Its character, measurement, and relationship to critical thinking skill,” Informal logic, vol. 20, pp. 61-84, January 2000.
22. P. A. Facione, C. A. Sanchez, N. C. Facione and J. Gainen, “The disposition toward critical thinking,” The Journal of General Education, vol. 44, pp. 1-25, January 1995.
23. P. A. Facione, N. C. Facione and C. A. F. Giancarlo, “The motivation to think in working and learning” New directions for higher education, vol. 96, pp. 67-79, December 1996.
24. C. A. Giancarlo, S. W., Blohm and T. Urdan, “Assessing secondary students’ disposition toward critical thinking: Development of the California Measure of Mental Motivation,” Educational and Psychological Measurement, vol. 64, pp. 347-364, April 2004.
25. K. Y. Ku and I. T. Ho, “Dispositional factors predicting Chinese students’ critical thinking performance,” Personality and Individual Differences, vol. 48, pp. 54-58, January 2010.
26. K. E. Stanovich and R. F. West, “Individual differences in reasoning: Implications for the rationality debate?,” Behavioral and brain sciences, vol. 23, pp. 645-665, October 2000.
27. J. S. B. Evans, “Dual-processing accounts of reasoning, judgment, and social cognition,” Annual Review of Psychology, vol. 59, pp. 255-278, January 2008.
28. E. J. Stupple, F. A. Maratos, J. Elander, T.E. Hunt, K. Y. Cheung and A. V. Aubeeluck, “Development of the Critical Thinking Toolkit (CriTT): A measure of student attitudes and beliefs about critical thinking,” Thinking Skills and Creativity, vol. 23, pp. 91-100, March 2017.
29. J. St. B. T. Evans, “Hypothetical thinking: Dual processes in reasoning and judgement,” New York: Psychology Press, 2007.
30. K. Frankish, “Dual‐process and dual‐system theories of reasoning,” Philosophy Compass, vol. 5, pp. 914-926, October 2010.
31. P.C. Abrami, R. M. Bernard, E. Borokhovski, D. I. Waddington, C. A. Wade and T. Persson, “Strategies for teaching students to think critically: A meta-analysis,” Review of Educational Research, vol. 85, pp. 275-314, June 2015.
32. D. Fung, “The pedagogical impacts on students’ development of critical thinking dispositions: Experience from Hong Kong secondary schools,” Thinking Skills and Creativity, vol. 26, pp. 128-139, December 2017.

33. D. Fung, "Promoting critical thinking through effective group work: A teaching intervention for Hong Kong primary school students," International Journal of Educational Research, vol. 66, pp. 45-62, 2014.
34. K. Y. Ku, I. T. Ho, K. T. Hau and E. C. Lai, "Integrating direct and inquiry-based instruction in the teaching of critical thinking: an intervention study," Instructional Science, vol. 42, pp. 251-269, March 2014.
35. CRITHINKEDU O2, A European review on Critical Thinking educational practices in Higher Education Institutions. Portugal: University of Trás-os-Montes and Alto Douro, 2018. ISBN: 978-989-704-258-4
36. D. F. Halpern, "Teaching critical thinking for transfer across domains: Disposition, skills, structure training, and metacognitive monitoring," American psychologist, vol. 53, pp. 449. April 1998.
37. R. Kachouie, S. Sedighadeli, R. Khosla and M. T. Chu, "Socially assistive robots in elderly care: a mixed-method systematic literature review," International Journal of Human-Computer Interaction, vol. 30, pp. 369-393, May 2014.
38. P. Pennisi, A. Tonacci, G. Tartarisco, L. Billeci, L. Ruta, S. Gangemi, and G. Pioggia, "Autism and social robotics: A systematic review," Autism Research, vol. 9, pp. 165-183, February 2016.
39. D. Feil-Seifer and M. J. Mataric, "Defining socially assistive robotics," 9th International Conference on Rehabilitation Robotics, pp. 465-468, Chicago: IEEE, June 2005.
40. I. Baroni, M. Nalin, M. C. Zelati, E. Oleari and A. Sanna, "Designing motivational robot: How robots might motivate children to eat fruits and vegetables," in 23rd International Symposium on Robot and Human Interactive Communication. Edinburgh, UK: IEEE, 2014, pp. 796-801.
41. D. Hood, S. Lemaignan and P. Dillenbourg, ''When children teach a robot to write: an autonomous teachable humanoid which uses simulated handwriting,'' in Proceedings of the tenth annual ACM/IEEE international conference on human-robot interaction, Portland, Oregon, USA: ACM, 2015, pp 83–90.
42. S. Spaulding, G. Gordon and C. Breazeal, "Affect-aware student models for robot tutors," in Proceedings of the 2016 international conference on autonomous agents & multiagent systems, Singapore: International Foundation for Autonomous Agents and Multiagent Systems Richland, SC, 2016, pp. 864-872.
43. R. M. Ryan and E. L. Deci, "Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being," American Psychologist, vol. 55, pp. 68-78, 2000.
44. M. K. Lee, J. Forlizzi, S. Kiesler, P. Rybski, J. Antanitis, and S. Savetsila, "Personalization in HRI: A longitudinal field experiment," in 7th ACM/IEEE International Conference on Human-robot interaction (HRI), Boston, USA: IEEE, 2012, pp. 319-326.
45. G. Gordon and C. Breazeal, "Bayesian Active Learning-Based Robot Tutor for Children's Word-Reading Skills," in Proceedings of the twenty-ninth AAAI conference on artificial intelligence, Austin Texas, USA: AAAI, 2015, pp. 1343-1349.
46. J. B. Janssen, C. C. van der Wal, M. A. Neerincx and R. Looije, "Motivating children to learn arithmetic with an adaptive robot game," in International Conference on Social Robotics. Berlin, Heidelberg. Germany: Springer, 2011, pp. 153-162.
47. A. Jones, S. Bull and G. Castellano, "I Know That Now, I'm Going to Learn This Next: Promoting Self-regulated Learning with a Robotic Tutor," International Journal of Social Robotics, vol. 9, pp. 1-16, November 2017.
48. A. Jones and G. Castellano, "Adaptive Robotic Tutors that Support Self-Regulated Learning: A Longer-Term Investigation with Primary School Children," International Journal of Social Robotics, vol. 10, pp. 1-14, January 2018.
49. N. Fachantidis, A. G. Dimitriou, S. Pliasa, V. Dagdilelis, D. Pnevmatikos, P. Perlantidis and A. Papadimitriou, "Android OS Mobile Technologies Meets Robotics for Expandable, Exchangeable, Reconfigurable, Educational, STEM-Enhancing, Socializing Robot," in Interactive Mobile Communication, Technologies and Learning. Advances in Intelligent Systems and Computing, M. Auer and T. Tsiatsos, Eds. Vol 725, pp. 487-497, Springer, Cham.
50. B. Scassellati, 2016, "Socially assistive robotics: an NSF expedition in computing," [Online]. Available: http://robotshelpingkids.yale.edu/overview.
51. I. Leite, C. Martinho and A. Paiva, "Social robots for long-term interaction: a survey," International Journal of Social Robotics, vol. 5, pp. 291-308, April 2013.
52. A. G. Carter, D. K. Creedy and M. Sidebotham, "Evaluation of tools used to measure critical thinking development in nursing and midwifery undergraduate students: a systematic review," Nurse education today, vol. 35, pp. 864-874, July 2015.