Socio-scientific Issues (SSI) in Chemistry Education: Enhancing Both Students’ Chemical Literacy & Transferable Skills

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Abstract
Chemistry education has tasks to guide students to be future employment within the field of science and engineering and also to provide societies with many opportunity for chemistry-related career. However, there are some challenges faced by chemistry education, such as lack of transferable skills of chemistry graduates, education reform on the need for scientifically literate citizens and for reducing the shortage in participation and interest of young people in science and engineering. One possible way to solve such challenges is that we could use socio-scientific issues (SSI) as a context to be integrated in a chemistry instruction. Through socio-scientific issues related chemistry, both scientific literacy and transferrable skills could be enhanced. This paper discuss potency socio-scientific issues in developing the skills and how to incorporate it in the instruction.

Keywords: Socio-scientific Issues, Chemical Literacy, Transferable Skill.

1. Introduction
Chemistry is the study of matter and its properties, the changes that matter undergoes, and the energy associated with those changes [1]. It is essential for many aspects in our daily lives and has many unexpected potential benefit for our future. An understanding of chemistry allows us to make sense of and explain phenomena happened around us. Through chemistry, we need to develop basic knowledge of how to live in this world, how to cope with daily life issues and how to act as individuals. For examples: how metal corrodes when it expose into air; how we can identify, choose, and use materials with respect to their properties; how we understand any potentials and risks of many modern chemistry related products and technologies. Futhermore, contemporary societies are increasingly confronted with questions underpinned by science (chemistry) with associated benefits, uncertainties and risks. For example: how to use wisely energy resources, how to secure sustainability in drinking water supply, how to deal with climate change challenges. It is obvious, then, these developments are significant to modern societies. They, in the future, individually or in groups will be asked critically reflect upon these issues, to contribute to societal debate related, and to make important scientifically-based decisions. Such issues that involve a science (including chemistry) dimension and that also raise a wide range of societal, political, economic and ethical considerations are often termed socio-scientific issues (SSI) [2].
Chemistry also provides societies with many opportunities for chemistry-related careers. Therefore, chemistry education should guide students to reach potential future employment within the field of science and engineering. Students need to have good knowledge in chemistry and about current trends in chemistry. Chemistry subject is not just important for careers within the field of science and engineering, but also for people who are working in law, economy or trade, who often deal with the issues of chemistry and its relationship to ecology, economy, or society [3]. However, there are some challenges faced by chemistry education.

- A growing body of evidence has shown that most chemistry graduates lack of generic/transferable skills that are essential for being efficient and productive members of the workplace [4,5]. These set of skills may include such as: problem solving, critical thinking, communication, team working, time management, independent learning [6,7]. Furthermore, there has been little studies conducted on the development of these skills within the chemistry curriculum although the fact that these issues have been well known for many years. Much of the chemistry education research literature still focuses on enhancing the knowledge and understanding of chemistry itself rather than developing those skills through the study of chemistry [8].

- There has been a widespread reform on science education in general and chemistry teaching in particular. The goals of such reform are the need for scientifically literate citizens [9] and for reducing the shortage in participation and interest of young people in science and engineering [e.g see 10]. The need in both fields was supported by several comprehensive reports regarding the state of science education in many countries e.g., in Before it is too late in 2000 (USA) by the John Glenn or Beyond 2000 (UK) in by Robin Millar and Jonathan Osborne.

According to Eilks & Hofstein [3], learning in chemistry allows for the development of a lot of general (transferable) skills and the chemistry itself should be taught in the best way possible to all students at secondary school level and at university level at the end. Therefore, to address the above issues (lack of transferable skills, the need for scientific literacy citizen and less interest of young people in science and engineering) we could maximize the chemistry in the classroom. One of possible ways is to incorporate issues related chemistry such as socio-scientific issues into chemistry teaching. This paper discuss about the potency of socio-scientific issues for addressing the above issues and its connection to improve scientific literacy, transferable skills and affective dimension and for meeting its challenges.

2. Discussion

2.1. The Important of Transferrable Skills in Chemistry Education

Skills can be defined as capabilities that individual should master for in a particular occupation or activity. There are many different kinds of skills needed in the 21st century. Leitch [7] categorize those skills into Basic skills (e.g literacy and numeracy) and Generic/Transferable skills (e.g team working and communication). Whereas, the World Economic Forum [11, cited in 12] identified 16 skills/capabilities and those 21st century skills grouped into three broad category, namely: (1) Foundational/basic literacies represent how students apply core skills to everyday tasks (e.g. literacy, numeracy, scientific literacy, ICT literacy; financial literacy, cultural and civic literacy); (2) Competencies describe how students approach complex challenges (e.g critical thinking, problem solving, creativity, communication & collaboration); (3) Character qualities describe how students approach their changing environment (e.g. curiosity, ininitiative, persistence/grit, adaptability, leadership, social and cultural awareness). Common generic/transferable/competency skills appear in the literature are critical thinking, problem solving, communication (oral & written), and collaboration. American Chemical Society (ACS) [13] share similar generic/transferable skills that should be developed by chemistry undergraduate students (e.g critical thinking, problem solving, working in a team, oral & written communication skills), besides other specific transferable skills such as laboratory safety skills. Most occupations use a mix of different kinds of skills and within each skill there are different levels of ability.
A study was conducted at the Year one and two chemistry undergraduate students (N=155) of university of Leicester on the perceptions of transferable and workplace skills development. The result showed that over 60% of respondents agreed that chemistry graduate should have all skills included in the questionnaire (i.e. the skills consisted of 20 skills divided of theoretical, practical & transferrable skills). Students (N=119) believed that most developed skills after experiencing a series of Context and Problem Based Learning (C/PBL) activities were problem solving, time management, working in a team and oral communication. The study also provided evidence to suggest that students believe that the “contextualized, real-world” problem was considered as an important aspect in determining the skills development [14]. Therefore, a contextualized and real world problem is necessary to be included in any chemistry instruction that is intended to develop those generic/transferable skills. In this case, socio-scientific issues (SSI) can be used as a context or real world problem included in an inquiry learning to achieve the purpose.

2.2. Chemical Literacy As The Goal of Chemistry Education
Education is an activity that is oriented towards the future. One of the education aims in the 21st century is to prepare individuals to live better and to become future workers [15]. In the field of science education, including chemistry education, its aim is to develop students to become educated citizens who have the ability and skills such as knowledge in the field of study (content knowledge), learning skills and thinking skills [16,17] and the realization of a society with scientific literacy [18]. Therefore, it is inevitable that educational practices must focus on efforts to improve student skills in scientific literacy [19] and identify the various capabilities needed by students in facing 21st century challenges such as challenges in the economic, social, technological and health fields [15]. In addition, trends in science education policies emphasize the importance of scientific literacy as a transferable outcome [20]. Therefore, the development of scientific literacy in students has become a top priority in the field of science education [21, 22]. Regardless the fact that the practice of science learning in various countries ignores the social dimension of science education and the promotion to develop skills needed by the students to be able to participate actively in society [23].

Scientific literacy is described in various ways [for example, see 24, 25, 26]. However, in general, the descriptions of scientific literacy cover three domains, namely: (1) knowledge about concepts and scientific ideas, (2) understanding of the process of scientific inquiry and the nature of knowledge produced (nature of science), (3) awareness of the influence of scientific activities on the social context in which the activity is carried out, and vice versa, the effects of everyday life, personal and social decisions on scientific ideas and practices [27, 28]. Chemical literacy is part of scientific literacy. Shwartz, Ben-Zvi, and Hofstein [29, 30] define chemical literacy through the domains of content, context, skills, and attitudes. They describe that chemically literate individuals should understand:

1. General Scientific Ideas: Chemistry is an experimental discipline in which chemists conduct scientific inquiry and provides knowledge used to explain phenomena in other areas.
2. Characteristics of Chemistry: a) explains phenomena in terms of macroscopic, sub-microscopic and symbolic representations; b) investigates the dynamics of processes & reactions and the energy changes during a chemical reaction; c) aims to understand and explain life in terms of chemical structures and processes of living systems; d) use a specific language.
3. Chemistry in Context: a) understand the importance of chemical knowledge in explaining everyday phenomena and relationship between chemistry innovations and sociological processes; b) use their understandings of chemistry in their daily life, in decision-making, and in participating in a social debate regarding chemistry-related issues.
4. High-Order Learning Skills: able to raise a question, searching information, analyse the advantages and disadvantages associated with a position in any debate. This skills are similar to inquiry skills.
5. Affective Aspects (e.g. curiosity, leadership, social and cultural awareness)
Scientific/chemical literacy provides aspirations for curriculum development, teaching materials and assessment practices, so that if materials and science/chemistry learning are facilitated with the domains mentioned above, students' scientific/chemistry literacy will develop [31, 32]. Within the domains, there are some transferable skills students should master to be a scientific literate citizen in the future, for example: inquiry skill, critical thinking skill, oral and written communication skill (argumentation, scientific explanation), problem solving skill, team working skill.

2.3 Socio-scientific Issues Related Chemistry and Its Teaching
Chemistry is basically about the abstract concept of the atomic theory of matter. A student has to portray the concept at various levels of representations (macroscopic, submicroscopic and symbolic representations) as described by Johnstone [33, 34] and this multi-representational structure is very important in studying chemistry [35]. Students start to study chemistry at secondary school level. However, there is a common criticism on the lack of connectedness of chemistry with the real world and the lives of the learners [36] and this situation is reinforced by the traditional chemical content and teaching approaches that are resistant to change. Generally, in the traditional classroom, chemistry is taught by memorisation of definitions and solving algorithmic type problems and the teacher rely most on the chemistry textbook. In order to develop scientific/chemical literacy of students, teaching approach should be active learning that use open-ended challenges requiring application of chemistry concepts and problem solving. A learning context is needed for application of concepts and problem solving activity.

Science educators have progressively promoted socio-scientific issue (SSI) as a learning context. SSI related chemistry is an important issue that develop in society that is conceptually related to chemistry. Socio-scientific issues (SSI) involve the purposive use of scientific (chemistry) topics in the instruction that obligate students to participate in dialogue, discussion, and debate. The characteristics of the issues are controversial and have the added component that need a degree of moral reasoning or the evaluation of ethical concerns in the process of justifying and finding possible solution of those issues [37]. Both inquiry activity and scientific knowledge are useful in the SSI negotiation process, because if only scientific activity implemented it will not be able to solve the SSI problem. Therefore, inquiry and SSI negotiation require the integration of scientific concepts and processes with social practices. Many educators argue that smart SSI negotiations are the foundation of modern scientific literacy for the nation and socio-scientific issue is an important element in current science learning [eg, 38, 39]. In the process of discussion, debate or dialogue on the SSI issues, the students use and develop some capabilities/skills and affective dimension. Transferable skills that could be used and developed in that learning context, for example: team working, oral & written communication (scientific explanation and argumentation), critical thinking, inquiry skills, problem solving. The following Picture 1 shows pedagogical relationship between teacher and students’ SSI discourse [Adapted from 40]. A chemistry teacher has competencies of subject matter and pedagogical content knowledge (PCK) and multidiciplinary life experiences. By drawn upon these competencies and experiences she/he could facilitate socio-scientific issues related chemistry to be presented to students in the classroom. The socio-scientific issues itself use appropriate scientific chemistry content that must be embedded in scientific and social context. The student, then, investigates personally relevant socio-scientific issues and discuss, debate or construct argument/explanation to solve the issues. Through some phases of learning the student could use and develop: knowledge of subject matter & nature of science (NOS), life experiences, some transferrable skills and affective dimension.
Table 1. Examples of Socio-scientific Issues Related Chemistry Derived from High School Curriculum

| Socio-scientific Issues         | Scientific Context          | Chemistry Content and Concepts                |
|--------------------------------|------------------------------|-----------------------------------------------|
| Alcohol                        | Medical benefit              | Reaction rate                                 |
| Monosodium glutamate (MSG)     | Medical benefit              | Hydrolysis                                    |
| Sodium benzoate                | Food preservatives           | Buffer                                        |
| Acidification                  | Acidification of Mediterranean| Acid base                                     |
| Acid Rain                      | Acid Rain in local area      | Acid, base, neutralization                    |
| DDT                            | Epidemic of disease          | Polarity of chemical bonds                    |

Implementation of teaching chemistry concepts by incorporating context of socio-scientific issues can be varied. However, in order to maximize scientific literacy skills and/or transferable skills, a teacher essentially should incorporate inquiry approach, explicit nature of science, socio-scientific issues related chemistry concepts that are studying. As illustration, in the activity regarding the use of sodium benzoate as preservatives, students are provided an opportunity to discover the active ingredient of a food preservatives, chemical reaction of sodium benzoate and its effects on specific area of brain and health. Furthermore, the involvement in classroom debates and discussion encouraged students to deal with
their beliefs about the benefit use of sodium benzoat as preservatives and their personal danger. In this kind of activity, students will actively involved in finding credible sources. They will read and evaluate critically conflicting evidence from credible sources and negotiating their conclusions within and against other groups of students. This type of activity also provides chance to observe the criteria students use in their selection of credible evidence. Through several phases of the classroom experience, students will be required to work individually, in small groups, and interact as a whole class. Their challenges will be in the form of reading articles with contradictory evidence from diverse sources, identifying crucial data and arguments, ranking the prominent of evidence, form group consensus positions, debate of positions, and evaluating other groups’ presentation of positions and evidence. The transferable skills involve in this phase will be inquiry skills (asking question, collecting data and evidence, analysing data, making conclusion), critical thinking, team working, communication (argumentation/scientific explanation), problem solving. Another skills could be used and developed such as independent learning and time management. Affective dimension use and develop could be curiosity, interest, moral awareness.

3. Conclusions
Enhancing scientific literacy skills, transferrable skills and young students’ interest towards science is a challenge for chemistry education. A study suggests the need to include a contextualized and real world problem in any chemistry instruction that is intended to develop those skills and affective dimension. By drawn upon competencies and experiences a chemistry teacher could facilitate socio-scientific issues related chemistry to students in the classroom. The socio-scientific issues itself use appropriate scientific chemistry content that must be embedded in scientific and social context. The student, then, investigates personally relevant socio-scientific issues and discuss, debate or construct argument/explanation to solve the issues. Through some phases of learning the student could use and develop: knowledge of subject matter & nature of science (NOS), life experiences, some transferrable skills and affective dimension. Examples of SSI related chemistry developed here are alcohol, MSG, sodium benzoate, acidification, DDT and acid rain.

References

[1] Silberberg MS. Principles of General Chemistry. 2nd ed. New York: McGraw-Hill; 2010.
[2] Ratcliffe M, Grace M. Science Education for Citizenship. Milton Keynes: Open University Press; 2003.
[3] Eilks I, Rauch F, Ralle B, Hofstein A. How to allocate the chemistry curriculum between science and society (p. 1-36). In Ingo Eilks, I & Avi Hofstein (Eds.). Teaching Chemistry — A Studybook: A Practical Guide and Textbook for Student Teachers, Teacher Trainees and Teachers. Rotterdam: Sense publishers; 2013.
[4] Ashraf SS, Marzouk SAM, Shehadi IA, Brian MM. An integrated professional and transferrable skills course for undergraduate chemistry students. J Chem Educ 2011;88: 44-48. doi:10.1021/ed100275y.
[5] Ministry of Research, Technology & Higher Education. Lampiran Peraturan Pemerintah No 50 Tahun 2017. Renstra Kemenristekdikti Tahun 2015-2019. http://www.kopertis12.or.id/2017/09/04/permenristekdikti-no-50-tahun-2017-tentang-renstra-kemenristekdikti-tahun-2015-2019.html (accessed September 13, 2018)
[6] Dearing R. Skills For Graduates In The 21st Century. Cambridge: The Association of Graduate Employers; 1995.
[7] Leitch, S. Leitch Review of Skills: Prosperity for all in the Global Economy — World Class Skills. London: Crown; 2006.
[8] Overton T, Mcearvey DJ. Development of Key Skills And Attributes In Chemistry. Chem Educ Res Pract 2017;18: 401-402. doi:10.1039/C7RP90006F
[9] DeBoer GE. Scientific Literacy: Another Look at Its Historical and Contemporary Meanings and Its Relationship to Science Education Reform. J Res Sci Teach 2000;37:582–601. doi: 10.1002/1098-2736(200008)37:6<582::AID-TEA5>3.0.CO;2-L

[10] Bøe MV, Henriksen EK, Lyons T, Schreiner C. Participation in science and technology: young people's achievement-related choices in late-modern societies. Stud Sci Educ 2011;47:37-72. doi: 10.1080/03057267.2011.549621

[11] World Economic Forum. New Vision for Education Unlocking the Potential of Technology. Geneva: World Economic Forum; 2015.

[12] Rahayu S. Promoting the 21st Century Scientific Literacy Skills through Innovative Chemistry Instruction. Development of Chemical Education in 21st Century Learning, New York: AIP Publishing; 2017, p.2.

[13] American Chemical Society (ACS). Development of Student Skills for Academic and Professional Success. https://www.acs.org/content/acs/en/education/policies/twoyearcollege/7--development-of-student-skills-for-academic-and-professional-s.html. (accessed July 20, 2018)

[14] Williams DP, Handa S. Chemistry Student Perceptions of Transferable & Workplace Skills Development New Directions in the Teaching of Physical Sciences. University of Leicester 2016;11:1-7. doi: org.io/10.29311/ndtps.v0i11.584

[15] Stevens R. Identifying 21st century capabilities. Int. J. of Learning and Change 2012; 6: 123–137. EJ1000234.

[16] Herscovitz O, Kaberman Z, Saar L, Dori YJ. The Relationship Between Metacognition and the Ability to Pose Questions in Chemical Education. In Zohar, Anat, Dori, Yehudit Judy (Eds.). Metacognition in Science Education: Trends in Current Research. Nederland: Springer;2012.

[17] Roberts DA, Bybee RW. Scientific literacy, science literacy, and science education. In N. G. Lederman & S. K. Abell ed.New York: Routledge;2014.

[18] Norris SP, Phillips LM. How literacy in its fundamental sense is central to scientific literacy. Sci Educ 2003;87: 224-240. doi:10.1002/sce.10066

[19] Cigdemoglu C, Arslan HO, Cam A. Argumentation to foster pre-service science teachers’ knowledge, competency, and attitude on the domains of chemical literacy of acids and bases. Chem Educ Res Pract 2017;18:288-303. doi: 10.1039/C6RP00167J

[20] Fives H, Huebner W, Birnbaum AS, Nicocho M. Developing a measure of scientific literacy for middle school students. Sci Educ 2014;98:549-580. doi:10.1002/sec.21115

[21] Sadler TD. Moral and ethical dimensions of socio-scientific decision-making as integral components of scientific literacy. Sci Educ 2004;13:39–48. EJ740943.

[22] Tytler R. Re-imagining science education: engaging students in science for Australia’s future. Victoria: ACER Press; 2007.

[23] Hofstein A, Eilks I, Bybee R. Societal Issues and their importance for contemporary science education: a pedagogical justification and the state of the art in Israel, Germany and the USA. Int J Sci Math Educ 2011;9:1459-1483. doi:10.1007/s10763-010-9273-9.

[24] Holbrook J, Rannikmae M. The Meaning of Scientific Literacy. Int J Env Sci Educ 2009;4:275-288. EJ884397.

[25] Gräber W, Erdmann T, Schlieker V. ParCIS: Aiming for Scientific Literacy through Self-Regulated Learning with the Internet. 2001:2-11. ED466362.

[26] Rychen DS, Salganik LH. Key competencies for a successful life and a well functioning society. Cambridge: Hogrefe & Huber; 2003.

[27] Ratcliffe M, Millar R. Teaching for understanding of science in context: Evidence from the pilot trials of the Twenty First Century Science courses. J Res Sci Teach 2009;46:945-959 doi: 10.1002/tea.20340

[28] Roth WM, Lee S. Science Education as/for participation in the community. Sci Edu 2004;88:263-291. doi: 10.1002/sce.10113
[29] Shwartz Y, Ben-Zvi R, Hofstein A. Chemical literacy: what it means to scientists and school teachers? J Chem Educ 2006a;83:1557-1561. doi: 10.1021/ed083p1557.
[30] Shwartz Y, Bez-Zvi R, Hofstein A. The use of scientific literacy taxonomy for assessing the development of chemical literacy among high-school students. Chem Educ Res Pract 2006b;7:203-225. doi: 10.1039/B6RP90011A.
[31] Roberts D. Scientific literacy/science literacy: threats and opportunities. in Abell S. K. and Lederman N. G. (Eds), Handbook of research on science education. New Jersey: Lawrence Erlbaum Associates; 2007.
[32] Shwartz Y., Ben-Zvi R. and Hofstein A. The importance of involving high-school chemistry teachers in the process of defining the operational meaning of ‘chemical literacy’. Int J Sci Educ 2005;27:323–344. doi:10.1080/0950069042000266191
[33] Johnstone AH. Teaching of chemistry—Logical or psychological? Chem Educ Res Pract 2000;1:9-15. doi: 10.1039/A9RP90001B
[34] Johnstone AH. You can’t get there from here. J Chem Educ 2010;87:22–27. doi:10.1021/ed800026d
[35] Gilbert JK, Treagust DF. Multiple representations in chemical education. Dordrecht: Springer;2009.
[36] Gabel, DL. The complexity of chemistry and implications for teaching. In B. J. Fraser & K. G. Tobin (Eds.), International handbook of science education. Dordrecht: Kluwer Academic Publishers; 1998.
[37] Zeidler DL, Nichols BH. Socio-scientific Issues: Theory and Practice. J Elementary Sci Educ 2009;21:49-58. doi:10.1007/BF03173684.
[38] Driver R, Newton P, Osborne J. Establishing the norms of scientific argumentation in classrooms. Sci Educ. 2000;84:287–312. Doi: 10.1002/sce.10025
[39] Zeidler DL, Walker KA, Ackett WA, Simmons ML. Tangled up in views: Beliefs in the nature of science and responses to socio-scientific dilemmas. Sci Educ 2002;86:343-367. Doi:10.1002/sce.10025
[40] Zeidler DL, Sadler TD, Applebaum S, Callahan BE. (2009). Advancing reflective judgment through socio-scientific issues. J Res Sci Teac 2009;46:74-101. Doi:10.1002/tea.20281

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