Confronting Students' Science Anxiety through "In Dialogue with Nature"

HOI Wan Heng Sandy, The Chinese University of Hong Kong, Hong Kong
WONG Wing Hung, The Chinese University of Hong Kong, Hong Kong
PANG Kam Moon, The Chinese University of Hong Kong, Hong Kong

The European Conference on Education 2017
Official Conference Proceedings

Abstract
Science anxiety is a common phenomenon among students taking traditional science courses, including some science-related general education courses. It has been observed that science anxiety hinders students from effective scientific literacy and confident application of science skills to solve problems. "In Dialogue with Nature" (UGFN1000) is a compulsory general education course for undergraduates of The Chinese University of Hong Kong. This course encourages students to engage in reading science texts and peer discussion about science-related issues, thereby clarifying misconceptions and building up confidence in seeing things from a scientific perspective. This study aims at investigating the change in students' science anxiety after they have taken UGFN1000, hence it brings insights into pedagogical development that could reduce students' science anxiety and improve their learning efficiency. We applied the "Science Anxiety Questionnaire" (SAQ) developed by Alvaro (1978) and found that science anxiety could be related to students' gender, faculty, and the gender of the teacher. Findings from focus group interviews suggested that the primary source of science anxiety roots in the 'fear of getting it wrong'. Preliminary analysis showed that UGFN1000 had made science more 'friendly' to students, and reduced the emotional burden of reading scientific articles and developed more concern for the world scientific issues. Several aspects of Nature of Science (NOS) were brought up in focus group interviews. It was hypothesized that lower anxiety towards science might be correlated with better understanding of NOS.

Keywords: Science Anxiety, Nature of Science (NOS), core-texts, general education, classics reading.

1. Introduction

1.1 General Education Foundation Programme

In 2012, the university curriculum changed from 3 years to 4 years in Hong Kong. Since then, a 6-unit General Education Foundation (GEF) Programme has become a compulsory component of the undergraduate curriculum at The Chinese University of Hong Kong (CUHK). GEF consists of two courses, namely "In Dialogue with Nature" (UGFN 1000) and "In Dialogue with Humanity" (UGFH 1000), in which students engage in direct dialogue with selected classics, teachers and fellow students to explore the world of science and knowledge, and to reflect on society and life. The courses are seminar-based. Every semester, all the ~3,800 students are divided into small groups of 25 each. Students discuss perennial issues brought up by the classics, which are relevant to contemporary context. Examples of issues include 'What is truth?' and 'What are the laws of life?'.

1.2 In Dialogue with Nature (UGFN 1000) – A core-text based general education course

This course brings students on an intellectual journey through (i) Exploration of the Physical Universe, (ii) Exploration of the World of Life, and reflection on (iii) Our Understanding of Human Understanding. Examples of core texts are excerpts from Plato's *Republic*, Charles Darwin's *On the Origin of Species* and Henri Poincaré's *Science and Methods*.

The assessment consists of three main components: reflective essays (50%), quizzes (25%) and participation (in-class & online discussions, 25%). By the end of the course, students are expected to be able to: (i) comprehend and discuss science-related texts, (ii) identify the essential characteristics of how human beings view nature, (iii) formulate informed personal views on the societal implications of scientific explorations, (iv) relate the developments in natural sciences highlighted in the course to contemporary human condition, and (v) evaluate the scopes of application, achievement and limitations of highlighted scientific methods using multiple perspectives.

1.3 Students' difficulties

UGFN 1000 is compulsory for all undergraduate students, regardless of their academic backgrounds. Students need to read science texts, write on and discuss scientific issues. In 2013/2014, we collected students' opinions on their learning difficulties in the course by a feedback form. It was found that their difficulties were mainly in three aspects: (i) Understanding the main ideas and details of each text, because of unfamiliar scientific concepts and terms, (ii) Language barrier of local students in reading English texts (even though the medium for teaching and in-class discussion was Cantonese) and (iii) Not being able to finish the reading before tutorial session.

In response to students' feedback, teachers of GEF Programme developed learning aids such as the mobile app 'DiaNable' (with study questions, paragraph outline and mini-dictionaries) (Cheung, Hoi, Ng, Pang, & Wong, 2017) and

micro-modules (online video clips) on basic scientific knowledge. These aids assisted students in tackling the cognitive component of difficulties. However, the emotional component in science learning was also notable. Some students showed anxiety towards science. This observation was consistent with the findings of existing studies (Jeffrey V Mallow & Greenburg, 1983).

Some students experience anxiety when confronting scientific knowledge, because of their previous lack of science background. A little amount of anxiety might motivate learning (Cassady & Johnson, 2002), but in the case of students studying science, it is rare that their anxiety level is too low. Instead their performance could be severely hindered because of their anxiety toward science (Anderson & Clawson, 1992). The frustration in studying science may also lead to disliking and avoiding anything scientific (Jeffry V Mallow, 1981), and even the lack of confidence and interest in making informed decision on scientific issues which a consumer or a citizen should do (Britner, 2008).

1.4 Science Anxiety

The phenomenon of Science Anxiety was identified by Mallow in 1977. It refers to a feeling of stress and tension that interfere with the acquisition of scientific knowledge, the development of scientific skills and abilities, and the application of science knowledge and skills, to daily life and in academic situations (Jeffry V Mallow, 1981). This anxiety is distinct from general test or performance anxiety but manifests itself as a crippling panic on exams in science classes. Students suffering from science anxiety, however, are often calm and productive in non-science courses (Jeffry V Mallow, 2006).

The cause of Science Anxiety is a lack of a framework of prior knowledge to help order new knowledge (Anderson & Clawson, 1992). On the other hand, it is also a mixture of baggage of poorly taught pre-college science, a lack of appropriate role models and societal prejudices. Therefore, it is indeed a baggage of cognitive and emotional burdens (Jeffry V Mallow, 2006).

It was suggested that lower achievement in science is related to higher levels of Science Anxiety, in both genders (Chiarelott & Czerniak, 1987; Czerniak & Chiarelott, 1985). Performance in any test is better if students could approach it with confidence, and analyze the problem calmly and rationally. Therefore, the two approaches to deal with Science Anxiety are reducing level of science anxiety (emotional burden), and improving instructional learning experience on science (cognitive burden) (Anderson & Clawson, 1992).

1.5 Science Anxiety Questionnaire (SAQ) (Alvaro, 1978; Jeffry V Mallow, 1981; Udo, Ramsey, Reynolds-Alpert, & Mallow, 2001)

It is a 44-item questionnaire with 22 science and 22 non-science analogous scenarios, such as ‘Filling your bicycle tires with the right amount of air’ (a science scenario) and ‘Precisely inflating a balloon to be used as apparatus in a Physics experiment’ (a non-science scenario). Students were asked to imagine how much they were frightened in those situations using a 5-degree Likert scale: “not at all”, “a little”, “a fair amount”, “much” or “very much”.

2. Results and Discussions

The following questions were thus addressed using Science Anxiety Questionnaire and focus group interviews:
1. Is there any change in students' Science Anxiety after they have taken "In Dialogue with Nature"?
2. If there is any, what are the possible factors contributing to the change?
3. What could be done to reduce their Science Anxiety and enhance their efficiency in learning?

2.1 Science Anxiety Questionnaire

Students in four semesters, namely 2014-15 Term 2, 2015-16 Term 1, 2015-16 Term 2, 2016-17 Term 1 were invited to fill in the SAQ twice on a voluntary basis, one at the beginning of the first lesson (Term start) and the other at the end of the last lesson (Term end). Since most students start to take the first GEF course (In Dialogue with Nature / In Dialogue with Humanity) in Term 2 of their first year, and the other in Term 1 of their second year, the students from 2014-15 Term 2 & 2015-16 Term 1 were from the same cohort, and so were those from 2015-Term 2 & 2016-17 Term 1. There are altogether 16 and 19 classes of 25 students from each cohort in the survey. Students were asked to fill in their student ID on the questionnaire, and after both term-start and term-end questionnaires were collected, only students who had completed both questionnaires were selected for data analysis.

Students who gave at least one "much" or "very much" response to any science or non-science question would be identified as generally anxious (GA); Students who gave at least one "much" or "very much" response to any science question would be regarded as science anxious (SA). The percentages of GA and SA students were calculated (Table 1).

	No. of students	**% SA**			**% GA**		
		Term start	Term end	Δ % SA	Term start	Term end	Δ % GA
First Cohort	265	64.91	60.00	**-4.91**	80.75	77.36	**-3.39**
Second Cohort	243	71.19	67.90	**-3.29**	86.83	80.66	**-6.17**

Table 1: Changes in Percentage of students who are science anxious (% SA), generally anxious (% GA), and their ratio (SA/GA), before and after taking UGFN 1000. % SA = 100 x (No. of SA students / Total No. of students); % GA = 100 x (No. of GA students / Total No. of students)

On the other hand, the average number of questions being answered "much" or "very much" (generally anxious, GA), and the average number of science question being answered "much" or "very much" (science anxious, SA) were calculated respectively. In this way, we could calculate the average change of each student (Table 2).

	No. of students	Average SA (Total 22 questions)			Average GA (Total 44 questions)		
		Term start	Term end	% Δ in Average SA	Term start	Term end	% Δ in Average GA
First Cohort	265	2.97	2.95	**-0.64**	6.73	6.26	**-7.00**
Second Cohort	243	3.70	3.63	**-1.89**	7.61	7.40	**-2.86**

Table 2: Changes in average number of science questions being answered "much" or "very much" among all students (Average SA) and changes in average number of questions being answered "much" or "very much" among all students (Average GA). After performing the paired *t* tests, no significant change was found.

From the above analysis, it was found that percentages of science and generally anxious students had been slightly reduced in both cohorts after taking our course (Table 1). Students were also generally less anxious and slightly less science-anxious after taking the course, by answering "much" and "very much" in fewer questions (Table 2), although the changes were not statistically significant.

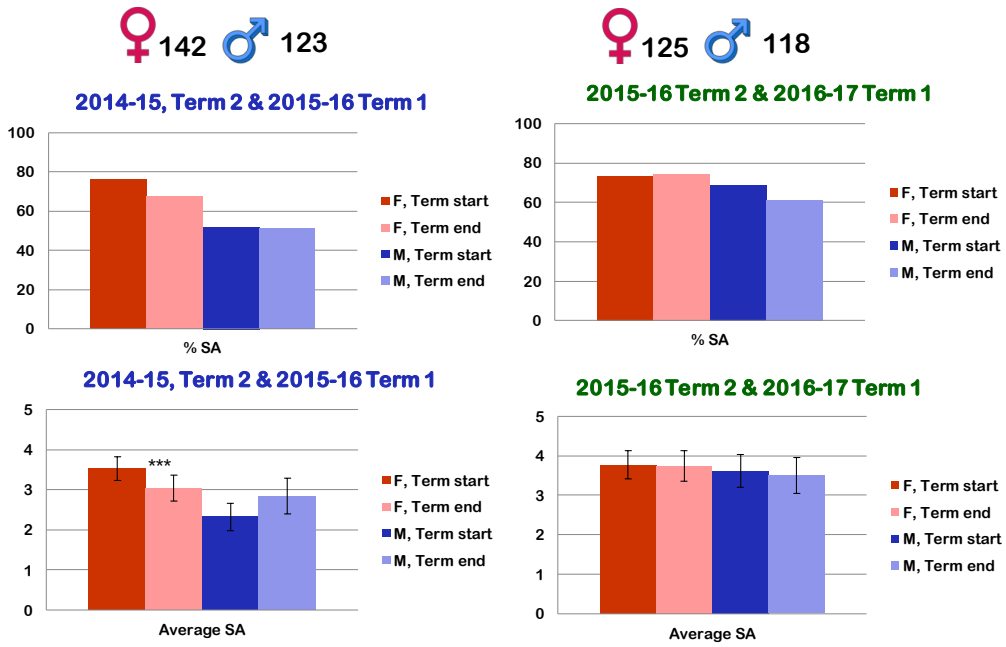

Figure 1: Percentages of SA students & Average number of SA questions being answered 'much' or 'very much' frightened by gender

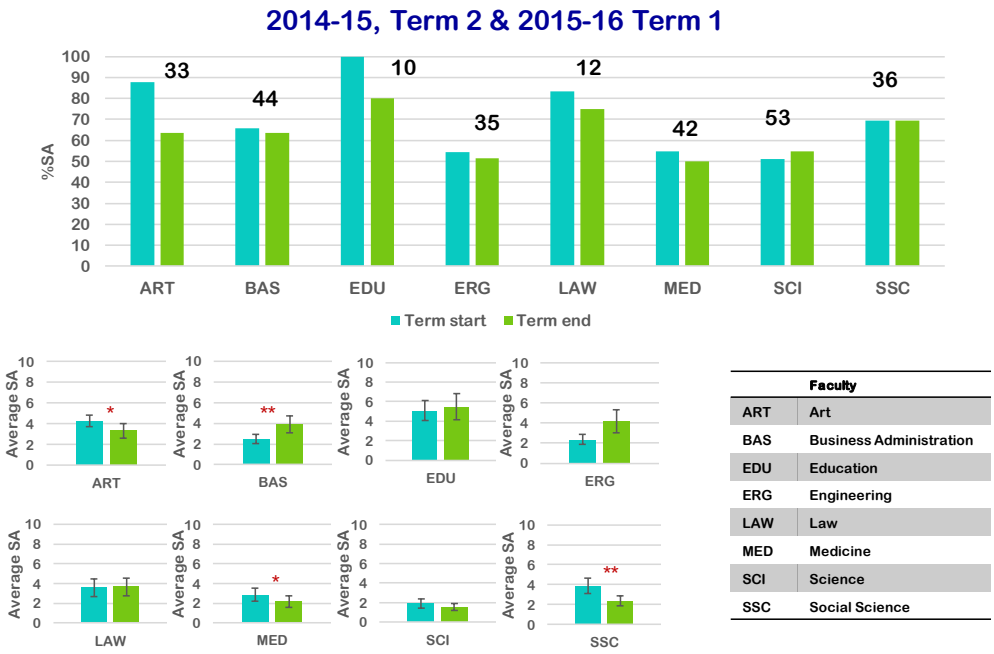

Figure 2: Percentages of SA students (top) & Average number of SA questions (bottom, left) being answered "much" or "very much" frightened by faculty in 2014-15 Term 2 & 2015-16 Term 1(First Cohort). Numbers above the bars refer to the number of students from each faculty in the study. The abbreviations of faculties are shown (bottom, right). Paired *t* test of average number of SA questions was carried out, *p<0.05, **p < 0.001.

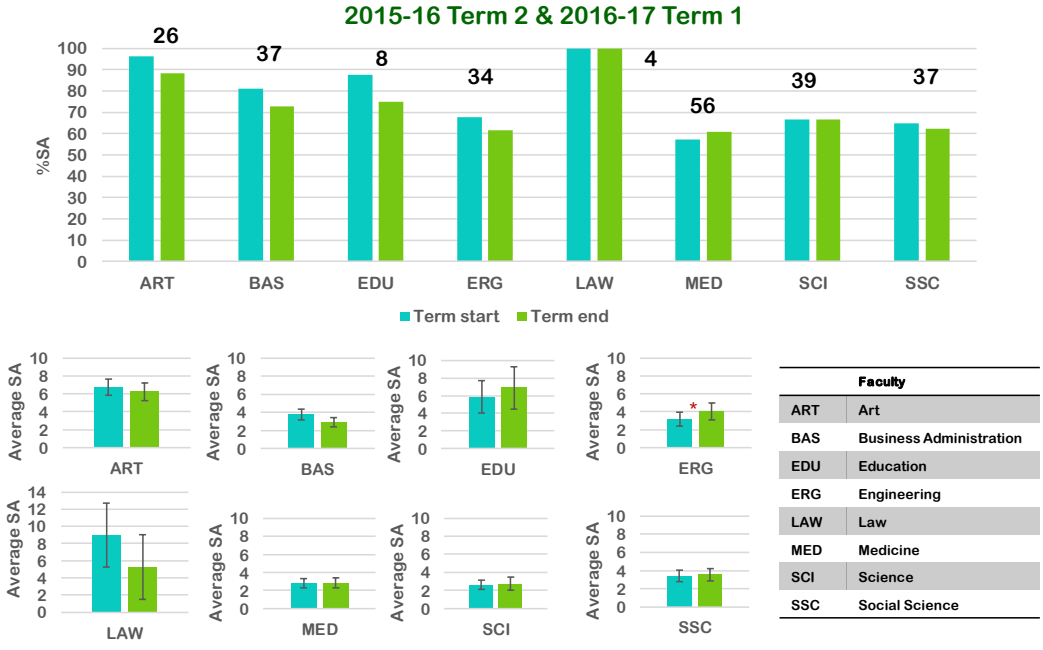

Figure 3: Percentages of SA students (top) & Average number of SA questions (bottom, left) being answered "much" or "very much" frightened by faculty in 2015-16 Term 2 & 2016-17 Term 1 (Second Cohort). Numbers above the bars refer to the number of students from each faculty in the study. The abbreviations of faculties are shown (bottom, right). Paired *t* test of average number of SA questions was carried out, *p<0.05.

Female students are generally more science anxious than male students, but their science anxiety reduced more significantly after taking "In Dialogue with Nature" (Figure 1).

Fewer students from most faculties tended to have science anxiety after taking "In Dialogue with Nature" (Figure 2 & 3). Nevertheless, the number of students varied in each faculty and needed to be increased for a more comprehensive comparison.

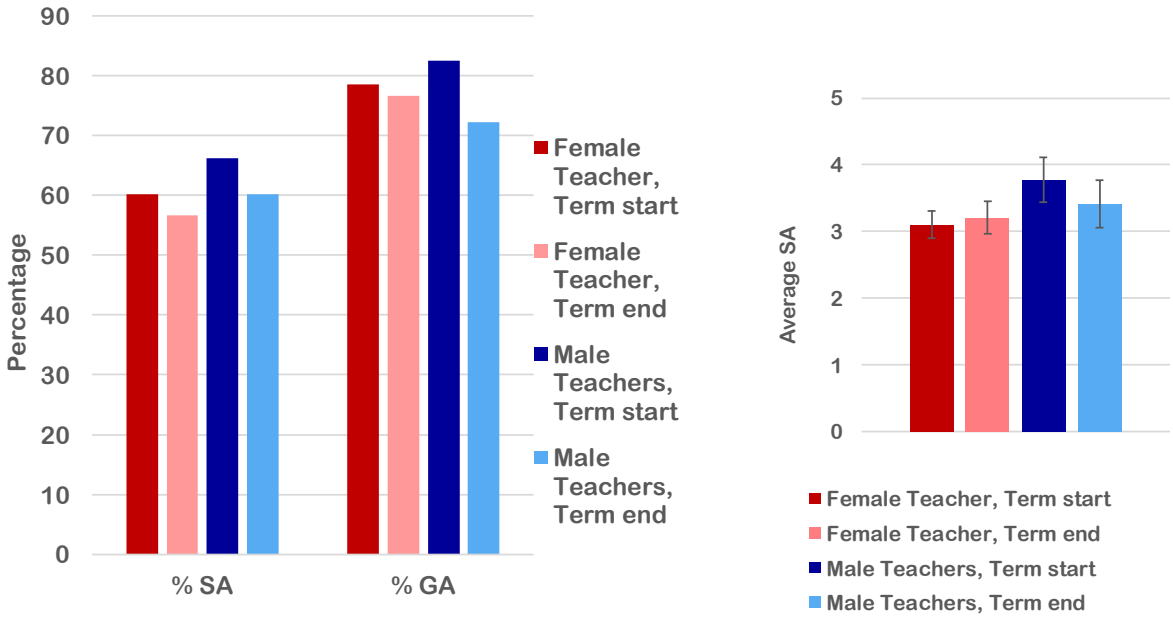

Figure 4 – Percentage of SA students & GA students, and average number of SA questions being answered "much" or "very much" frightened, by teacher's gender in both cohorts. Number of students being taught by a female teacher was 342 and two male teachers was 166.

Whether teachers' gender affects students' science anxiety was also investigated. The percentages of SA and GA students reduced after taking the course, with both female and male teachers. A higher percentage of students taught by male teachers were science anxious (Figure 4, left). The average number of science questions being answered "much" and "very much" reduced after the students had taken the course taught by male teachers, although the reduction was not statistically significant (Figure 4, right). The finding also reflected the tendency of generally anxious and science anxious students in choosing male teachers for this course.

The general reduction of science anxiety could be due to their learning experience in UGFN 1000 per se or other experiences throughout the semester. A focus group interview was thus carried out to find out the students' sources of science-related anxiety in our course specifically, and hopefully bringing insight into the pedagogical development.

2.2 Focus Group Interview

Seven local students (taught by three teachers) taking "In Dialogue with Nature" in 2015-16 first term were interviewed. Their information is as follows:

Identity	Gender	Year of study	Faculty
P1	Female	2	Law
P2	Male	2	Business
W1	Female	2	Business
W2	Male	2	Social Science
S1	Female	2	Social Science
S2	Male	2	Science
S3	Male	2	Engineering

Table 3 – Information of students participated in Focus group interview

The aim of this interview was:

1. To find out students' sources of science-related anxiety in "In Dialogue with Nature".
2. To understand how the learning activities in "In Dialogue with Nature" affect these sources of science anxiety, and how the effects are related to the background of students.

Interview questions and students' responses – excerpt.

- ***Which component of learning (or assessment) in our course generates the greatest anxiety?***

Three students answered written assignments ('Reflective Journal & Term Paper'), three answered 'Quizzes', one answered 'Group discussion'.

S1: 'I'm afraid of misinterpreting the ideas of the texts and making mistakes in writing papers and doing quizzes. Therefore I felt anxious working on these.'
P1: 'Term paper leads to the greatest pressure. I was afraid what I had written didn't match the requirement of questions. Same as reflective journal, reflection is crucial, but I'm not sure if mine could fulfill the criteria in this course.'
The source of this science anxiety could be pin-pointed to the '**fear for getting it wrong**'. It was because wrong answer could affect their Graded Point Average (lower marks in quizzes and written assignments), as well as causing the shameful feeling in group discussion.

- ***Is there any difference reading a text that will be quizzed on and reading one that won't?***

W2: 'Certainly there's a difference because the quizzes count towards my final grade…When I read the texts that didn't need to be quizzed, I didn't read them attentively, and I just tried to grasp the outline of the whole text…'
S1: 'When there is no quiz, I can enter the classroom with doubts without feeling nervous…I felt more relaxed. '
W1: 'Frankly speaking, I haven't read all the texts in UGFN except those that needed to be quizzed. '

It could be concluded that quizzes could increase anxiety but also the motivation to read the core-texts.

- ***Is there any change in the way you feel about science after taking the course?***

S2: 'The course has given me a positive feeling about science. I used to think that science is 'professional' stuff. I just memorize the equations and stuff facts into my head. But in this course the teacher taught science in a lively way…we were exposed to different scientific issues. It allowed us to develop our interests and not to feel anxious.'

S2: 'Now I'm more confident and motivated to read any article about neuroscience after learning related knowledge in this course. In the past I felt it was terribly hard even before I started reading.'

S3: 'Actually some texts covered in this course are warnings to the world, e.g. GM food, Silent Spring…These texts are about damages brought about by science, and make us ponder and judge human behaviour towards Nature. l will now keep an eye on related news. With basic knowledge, maybe our generation could make some change to the world.'

The course has made science more 'friendly' to students, and the emotional burden to read science articles has been reduced. On the other hand, they have developed more concern for scientific issues around the world.

- ***What could reduce your science anxiety in taking this course? What could we do to increase your confidence?***

1. Mobile app 'DiaNable' developed by a team of teachers in General Education Foundation Programme (Cheung, et al., 2017).

W2: 'I could evaluate my understanding of texts with this app. If I've answered it wrongly, I could be reminded & make improvement. In this way I could be more sure about the messages from texts, and reduce some anxiety…This app is really helpful.'

2. Connections between scientific knowledge and daily life.

S1: 'I remember when we learned about mechanics, our lecturer mentioned an example of 'flinging away the cockroach on your arm' to illustrate Newton's laws, it was very impressive.'

W2: 'There was a role play discussion (about population policies under 'Social Darwinism & Eugenics') in a tutorial lesson, each group represented different stands, and we had to discuss based on our role. It would be nice to have more discussion in this style, the atmosphere would be more relaxing and engaging, not just focusing on boring texts.'

Other suggestions include teacher's guidance on how to write a term paper, teachers being smiley and encouraging when students answer questions in front of class and

3. Peer assistance – online discussion

S3: 'When I prepared for my term paper, I viewed my classmates' replies in the online discussion broad. I felt much more comfortable to find a majority of replies sharing the same view as mine.'

Apart from the cognitive support on understanding the texts, it was remarkable that emotional components including teachers' attitude, peers sharing and their connection with science could also reduce the burden of studying science-related issues.

From the focus group interview, we have also discovered students' recognition of several aspects of **Nature of Science** (NOS), it was hypothesized that better understanding of NOS might be related to lower anxiety towards science.

S1: 'In the past I felt like science has an absolute truth. But then I knew that those theories that were regarded as true could be overthrown with new evidence, I feel like science is not true in full reality. I recalled the shadows in the Allegory of the Cave, although it wasn't fake, it's just not that real.'

The scientific knowledge is both tentative and durable (**Tentativeness of Scientific Knowledge**), and both scientific laws and theories are subject to change (**Scientific Theories and Laws**) (Liang et al., 2006).

*S2: 'I remember a text was about whether we could use science to prove the existence of free will…This make me think of these questions: 'Can science explain everything? Or does it create more questions?'*Science aims to be objective and precise, but subjectivity in science is unavoidable (**Subjectivity and Objectivity in Science)** (Liang, et al., 2006).

W1: 'Some authors from the texts have spent their whole lives in research, published papers until the day they died. I studied science in high school, but I don't think I have such patience and perseverance. They could even get no result spending their whole life working on the same area, or have their theories proven after they died. I really admire this spirit and it is remarkable as a human being.'

Science is part of social and cultural traditions (**Social and Cultural Embeddedness in Science**) (Liang, et al., 2006).

3. Conclusion & Recommendations

The analysis of student responses to the Science Anxiety Questionnaires showed that more than half of our students were science anxious, and the root of their anxiety seemed to be the "fear for getting it wrong", which would affect not only their grades but also the impression on their peers.

The percentage of science anxious students dropped, and the average number of science questions being answered "much" or "very much" frightened was slightly reduced after students had taken "In Dialogue with Nature". This suggests a room for pedagogical improvement. Some insights were brought up by students in the focus group interview. Not only the cognitive support like a mobile app with study questions, teacher's guidance on reading science core-texts and on writing are significant, the "fear for getting it wrong" could also be alleviated with affective support like teachers being supportive and encouraging, and the sense of connections between scientific knowledge and daily life. Not only teachers could provide support, the mutual influence among peers was also significant. Establishing an encouraging discussion environment and space for peers sharing is thus essential.

Inspired by the above results from our study, we propose a further study that includes the following two main components:

1. To develop a new survey tool to evaluate the relationship between students' science anxiety and other factors.

Alvaro's Science Anxiety Questionnaire (Alvaro, 1978; Jeffry V Mallow, 1981; Udo, et al., 2001) that we adopted previously contains 44 questions, some items belong to

sub-categories of science anxiety unrelated to the context of our science core-texts based course. For example 'Lighting a Bunsen burner in the preparation of an experiment' is related to 'Danger Anxiety' (Wynstra & Cummings, 1993), but there is no laboratory lesson in our course. Moreover the SAQ was designed for American students and it was therefore written in English. It was very likely that there was a language barrier for Hong Kong students, whose first language is Chinese. A new questionnaire written in Chinese, being more culturally applicable to Hong Kong students and more relevant to the context of our course, is therefore to be developed.

More information (new parameters) from students will be obtained with the new questionnaire, for instance background knowledge (whether they have studied any science-related subjects in secondary school), understanding of nature of science (NOS), their self-efficacy towards science, in addition to faculties, year of study and gender.

2. To design pedagogical interventions to reduce students' Science Anxiety and improve their learning efficiency.

The result obtained could let teachers better understand their students and thus adjust their pedagogical approaches for better learning efficiency, and even better scientific literacy. Examples of possible interventions include correction of science-related negative self-statements, and muscle relaxation exercises before quizzes and class discussions.

Acknowledgement

This research was supported by the Bamboo Grants Program of the United Board for Christian Higher Education in Asia (Project code: 6904444).

References

Alvaro, R. A. (1978). *The effectiveness of a science-therapy program on science-anxious undergraduates.* Doctoral dissertation, Loyola University of Chicago, Chicago.

Anderson, G. A., & Clawson, K. (1992). Science Anxiety in Our Colleges: Origins, Implications, and Cures.

Britner, S. L. (2008). Motivation in high school science students: A comparison of gender differences in life, physical, and earth science classes. *Journal of Research in Science Teaching, 45*(8), 955-970. doi: 10.1002/tea.20249

Cassady, J. C., & Johnson, R. E. (2002). Cognitive test anxiety and academic performance. *Contemporary educational psychology, 27*(2), 270-295.

Cheung, D. H., Hoi, S. W., Ng, A. K., Pang, K., & Wong, W. (2017). *Dianable: A Reading-Companion Mobile App for Science Core-text Teaching at The Chinese University of Hong Kong.* Paper presented at the Teaching and Learning with Technology: Proceedings of the 2016 Global Conference on Teaching and Learning with Technology (CTLT 2016).

Chiarelott, L., & Czerniak, C. (1987). Speaking Out: Science Anxiety: Implications for Science Curriculum and Teaching. *The Clearing House, 60*(5), 202-205.

Czerniak, C., & Chiarelott, L. (1985). Science Anxiety among Elementary School Students: Equity Issues. *Journal of Educational Equity and Leadership, 5*(4), 291-308.

Liang, L. L., Chen, S., Chen, X., Kaya, O. N., Adams, A. D., Macklin, M., & Ebenezer, J. (2006). *Student Understanding of Science and Scientific Inquiry (SUSSI): revision and further validation of an assessment instrument.* Paper presented at the Annual Conference of the National Association for Research in Science Teaching (NARST), San Francisco, CA (April).

Mallow, J. V. (1981). *Science anxiety: Fear of science and how to overcome it*: Thomond Press.

Mallow, J. V. (2006). Science anxiety: research and action (pp. 325-349): NSTA Press. Virginia, USA.

Mallow, J. V., & Greenburg, S. L. (1983). Science anxiety and science learning. *The Physics Teacher, 21*(2), 95-99.

Udo, M., Ramsey, G., Reynolds-Alpert, S., & Mallow, J. (2001). Does physics teaching affect gender-based science anxiety? *Journal of Science Education and Technology, 10*(3), 237-247.

Wynstra, S., & Cummings, C. (1993). HIGH SCHOOL SCIENCE ANXIETY: Easing common classroom fears. *The Science Teacher, 60*(7), 18-21.

Contact email: sandyhoi@cuhk.edu.hk