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Reflections on Practice

Life Science Courses Embedded with Active Learning Activities: Opportunities for Developing Higher Order Thinking (HOT) Skills and Graduate Employability Skills-Attributes (GESA)

LAM Siew Hong, CAI Hongxia, and XU Weiting
Department of Biological Sciences, Faculty of Science, National University of Singapore

ABSTRACT

The need to equip our graduates with HOT skills and GESA becomes essential in this post-truth world and automation era. The learning of HOT skills and GESA can be embedded in our curriculum using active learning strategies. To reflect on whether our Life Science (LS) curriculum has opportunities to develop HOT skills and GESA via active learning, we conducted and analysed an online survey on 90 LS courses. Among the 20 learning activities, "Report/Essay Writing" (62%), "Project Work" (58%), "Critical Reading & Critique" (58%), and "Case Studies" (56%) are the most embedded activities. As for the four HOT skills based on Bloom's taxonomy, i.e., "Apply", "Analyse", "Evaluate", and "Create", there are respectively 91%, 90%, 87%, and 72% of the LS courses perceived by the course coordinators to have "Good" to "Very Good" opportunities for developing them. Among the 14 GESA items, 54% to 99% of the LS courses are perceived to have "Good" to "Very Good" opportunities for developing them; "Analytical & Critical Thinking" and "Problem-solving" skills are among the highest. An indirect comparison with another independent survey on our graduates' perception of learning GESA suggests comparable findings, although there is room for improvement. Overall, the findings suggest that our LS curriculum, embedded with active learning activities, offers good to very good opportunities for developing HOT skills and GESA.

Keywords: Active Learning, Higher Order Thinking (HOT) Skills, Graduate Employability Skills-Attributes (GESA), Life Science Curriculum

Correspondence: Assoc. Prof. LAM Siew Hong (dbslsh@nus.edu.sg)

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INTRODUCTION

GESA can be viewed as “work-ready” skills (e.g., collaboration, communication, teamwork), cognitive skills (including HOT skills), and personal traits (e.g., learnability, self-efficacy, resilience) of fresh graduates that are relevant and desirable for employment and the workforce (Wong et al., 2022). These skills are becoming ever more important in this post-truth era, with the use of artificial intelligence and automation expanding in our workplace. HOT skills are needed to sift through the information deluge for verification, application, synthesis, and/or decision-making. GESA will enable our graduates to learn and adapt to rapid change while maintaining the invaluable “human touch” at the expense of automation in our workplace. Moreover, employers perceive that graduates with such skills and attributes will perform better in the workplace, and they expect universities to produce graduates who are “work-ready” (Sarkar et al., 2020; Succi & Canovi, 2020).

However, unlike the teaching and learning of disciplinary hard/technical skills, which are taught systematically in a structured curriculum and evaluated within well-defined learning outcomes, soft skills, as in GESA, are less tangible and harder to measure and, hence, are usually not taught or evaluated explicitly (Rook & Sloan, 2021). Some academics are of the opinion that “soft” skills are better learned or developed by the students themselves when opportunities are presented in academic or non-academic settings (Sarkar et al., 2020; Smith, 2012). In the academic settings, there are generally two approaches in training and developing soft skills: 1) the “parallel bolt-on” approach which trains soft skills in stand-alone courses/platforms that are bolted onto the curriculum and are running in parallel with, but separately from, other disciplinary courses, and 2) the “embedded built-in” approach where the training of soft skills are embedded and built into the disciplinary courses (Cranmer, 2006). While both approaches have their pros and cons, the “embedded built-in” approach has been perceived more favourably as the development of these skills can be done together with the learning of disciplinary content without the need to make extensive changes to the curriculum (Lam & Ip, 2018). The opportunities to exercise these skills are usually embedded and built into the assignments and projects, especially those that involve active learning activities.

Active learning activities are learner-centred activities that engage learners to think actively about what they are learning and to integrate new information and experience into their existing knowledge (Michael, 2006; Prince, 2004). Instead of passively receiving information, active learning activities engage learners to build understanding, construct knowledge, and even acquire skills above and beyond listening to a lecture and note-taking (Handelsman et al., 2007). These learning activities often involve peer interaction or group work, and therefore, require learners to exercise interpersonal skills such as collaboration, teamwork, and communication skills (Freeman et al., 2014). Active learning assignments such as project work and research study would require critical-analytical thinking, problem solving, planning, and organisational skills to carry them out. Moreover, these learning activities also offer opportunities to develop ethics awareness, self-efficacy, learnability, and resilience. As learners interact actively with the learning materials and perform the activities within the social environment, the development of HOT skills and GESA can be promoted (Freeman et al., 2014).

Considering that the development of GESA can be built into active learning activities, the main thrust of this reflection is to determine and reflect on the extent of active learning activities

embedded in our Life Science (LS) courses and the opportunities for the development of GESA as perceived by the course coordinators. An earlier exploratory study revealed that the academic staff of NUS Department of Biological Sciences (DBS) agreed that equipping our undergraduates with generic soft skills is important, and the development of some of these skills, which are found lacking in our undergraduates, is needed in our courses (Lam & Ip, 2018). A more recent survey study suggested that there was a good awareness of active learning activities and a strong interest in employing them among DBS academic staff (Lam et al., 2022). Building on the findings of these two studies, we collated course information from the LS course coordinators, analysed it, and reflected on the following questions:

What are the types and the extent (in percentage) of active learning activities embedded in our LS courses?

What are the learning opportunities for developing HOT skills and GESA in our LS courses as perceived by course coordinators?

We further reflected on the perceived learning of soft skills by our DBS graduates from another independent survey (Graduate Employment Survey 2022) and compared indirectly with our findings to suggest room for improvement.

APPROACH AND REFLECTIONS

As part of our exercise to update the information of our LS undergraduate courses with the implementation of the College of Humanities and Sciences (CHS) curriculum, we have requested additional information on the active learning activities and perceived learning opportunities for HOT skills and GESA that are embedded in these courses. The online Qualtrics platform was used to collate information from a total of 90 LS courses (coded as LSM) that were offered from level 1000 to 4000. The collated information was analysed specifically to allow us to determine and reflect on the type and extent of active learning activities embedded in our LS courses, and the perceived learning opportunities to develop HOT skills and GESA.

Active learning activities embedded in LS courses

Among the 20 active learning activities listed in Table 1, “Report/Essay Writing” (62%), “Project Work” (58%), “Critical Reading & Critique” (58%), and “Case Studies” (56%) are the most commonly embedded learning activities across the 90 LS courses. These activities are useful for learning fundamental or advanced concepts, and can be adapted easily for a large or small class. It is not surprising that “Role-playing” (4%) and “Debates” (7%) are the least embedded learning activities, as only a few of the advanced level 3000 and 4000 courses that teach more specialised topics and have a smaller class size, which favour the implementations of these activities. On the other hand, learning activities such as “Self-assessment or Quiz”, “Interactive lecture”, and “Inquiry-based learning” are useful for formative learning of fundamental concepts and are amenable to larger class sizes, hence popular among level 1000 and 2000 courses. It is noteworthy that over half (54%) and one third (34%) of the LS courses contain laboratory activities and expedition/field/site visits, respectively, which provide hands-on or experiential learning. It is worth mentioning that about 87% (78/90) of the courses are embedded with five or more active learning activities (data not shown). Besides engaging learners to develop understanding and construct knowledge, active learning promotes the development of HOT skills and GESA through the learning activities (Hui et al., 2021; Walker,

2003). Hence, the high percentage of LS courses embedded with active learning activities suggests greater opportunities for developing these skills and attributes in the courses.

Table 1. Active learning activities embedded and built into Life Science (LSM) courses*.

Active Learning Activities@	Percentage within each level# (Number of LSM courses)				Percentage across all levels^ (n=90)
	Level 1000 (n=4)	Level 2000 (n=17)	Level 3000 (n=34)	Level 4000 (n=35)	
Report/Essay Writing	25%(1)	53%(9)	71%(24)	60%(21)	62%
Critical Reading & Critique	50%(2)	41%(7)	50%(17)	75%(26)	58%
Group/Individual Project	50%(2)	47%(8)	53%(18)	69%(24)	58%
Case Studies	75%(3)	53%(9)	56%(19)	55%(19)	56%
Group/Individual Presentation	75%(3)	24%(4)	50%(17)	69%(24)	54%
Laboratory Activities (Wet/Dry)	50%(2)	65%(11)	71%(24)	32%(11)	54%
Self-Assessment or Quiz	100%(4)	47%(8)	59%(20)	38%(13)	50%
Interactive Lecture	75%(3)	65%(11)	50%(17)	35%(12)	48%
Group Discussion or Discussion Forum	25%(1)	41%(7)	59%(20)	38%(13)	46%
Problem-based Learning	50%(2)	65%(11)	33%(11)	40%(14)	43%
Inquiry-based Learning	75%(3)	41%(7)	36%(12)	38%(13)	39%
Expedition/Field Trip/Site Visit	50%(2)	29%(5)	33%(11)	35%(12)	34%
Peer Review and Feedback	50%(2)	29%(5)	33%(11)	35%(12)	34%
Student Generated Questions	25%(1)	29%(5)	30%(10)	32%(11)	30%
Hands-on Technology	0%(0)	18%(3)	33%(11)	29%(10)	27%
Peer-Learning	50%(2)	18%(3)	33%(11)	15%(5)	24%
Concept Mapping	0%(0)	18%(3)	24%(8)	12%(4)	17%
Games	50%(2)	12%(2)	12%(4)	6%(2)	12%
Debates	0%(0)	0%(0)	6%(2)	12%(4)	7%
Role Playing	0%(0)	0%(0)	6%(2)	3%(1)	4%

* **Instruction:** Indicate the types of learning activities and assignments used to achieve the intended learning outcomes of knowledge, cognitive and skills development in this course [You may select more than one]

@ The list of active learning activities is derived and expanded from the Center for Research on Teaching and Learning, University of Michigan (https://crlt.umich.edu/active_learning_implementing) and Lam et al. (2022).

Percentage within each level is calculated based on the number of courses employing the specific active learning activity divided by the total number of courses within each level.

^ Percentage across all levels is calculated based on the total number of courses employing the specific active learning activity divided by the total number of courses across all levels.

Perceived learning opportunities for developing HOT skills and GESA

Among the six cognitive abilities, including the four HOT skills based on the revised Bloom's taxonomy for cognitive domains (Krathwohl, 2002), 71% to 97% of the LS courses were perceived by the course coordinators to have "Good" to "Very Good" opportunities to develop them (Table 2). "Understand" followed by two HOT skills, "Apply" and "Analyse", have the highest percentage (90% to 97%) of courses with "Good" to "Very Good" opportunities to develop them. As for HOT skills "Evaluate" and "Create", there are better opportunities to develop them in the more advanced level 3000 and 4000 courses compared to the level 2000 courses. This is likely because the learning activities and assignments, such as report/essay writing, critical reading & critique, projects, and presentations, tend to involve these HOT skills and are embedded in higher percentages of the more advanced courses. For example, there are 50% to 75% in level 3000/4000 courses compared to 24% to 53% in level 2000 courses that involved report/essay writing, critical reading & critique, projects, and presentations (Table 2). Such learning activities have been shown to promote HOT skills (Hugerat & Kortam, 2014; Quitadamo & Kurtz, 2007).

Table 2. Perceived "Good" and "Very Good" learning opportunities for developing cognitive abilities, including HOT skills*.

Cognitive Abilities including Higher Order Thinking (HOT) Skills@	**Percentage rated "Good" and "Very Good" opportunities within each level# (Number of LSM courses)**				**Percentage across all levels^ (n=90)**
	Level 1000 (n=4)	**Level 2000 (n=17)**	**Level 3000 (n=34)**	**Level 4000 (n=35)**	
Remember: Recognise, Recall & Know	75%(3)	59%(10)	65%(22)	83%(29)	71%
Understand: Question, Connect & Explain	100%(4)	94%(16)	94%(32)	100%(35)	97%
Apply: Use, Execute & Implement	100%(4)	94%(16)	97%(33)	83%(29)	91%
Analyse: Differentiate, Organise & Attribute	75%(3)	88%(15)	88%(30)	94%(33)	90%
Evaluate: Review, Check & Critique	100%(4)	71%(12)	82%(28)	97%(34)	87%
Create: Ideate, Plan, Generate & Produce	75%(3)	59%(10)	71%(24)	80%(28)	72%

* Instruction: Please estimate and rate the opportunities for students to develop the following cognitive abilities based on the learning activities and assignments in the course (Likert scale 1=Very Poor; 2=Poor; 3=Average; 4=Good; 5=Very Good).

@ The cognitive abilities are based on the revised Bloom's taxonomy, where HOT skills include the ability to apply, analyse, evaluate and create (Krathwohl, 2002).

Percentage within each level is calculated based on the number of courses that were rated "Good" and "Very Good" divided by total number of courses within each level.

^ **Percentage across all levels** is calculated based on the total number of courses that were rated "Good" and "Very Good" divided by the total number (n=90) of across all levels.

Among the 14 GESA items listed in **Table 3**, 54% to 99% of the LS courses were perceived by the course coordinators to have "Good" to "Very Good" opportunities to develop them. "Analytical & Critical Thinking" and "Problem-solving & Decision-making" skills have the highest percentage (99% and 91%) of courses with "Good" to "Very Good" opportunities to develop them. This is not surprising as such skillsets are commonly required; hence, the

opportunities to learn and practice them can be easily created and frequently embedded in various types of assignments and learning activities across all levels of LS courses. As “Ethics Awareness”, “Quantitative Thinking”, “Digital Information & Literacy”, and “Planning, Organisational & Management skills” are not the primary requirement or emphasis in some of the LS courses, there may be relatively fewer opportunities to develop them. It appears that there are better opportunities for students to develop “Written Communication”, “Interdisciplinary Thinking”, “Collaboration & Teamwork”, “Adaptability & Learnability”, “Verbal/Oral Communication skills”, and “Self Efficacy” in level 3000 and 4000 courses than in level 2000 courses. The reason may be that the more advanced courses tend to involve complex interdisciplinary problems in projects or assignments that require written reports, presentations and group work (from 50% to 71% in level 3000 or 4000 courses compared to 24% to 53% in level 2000 courses), hence creating more opportunities to develop the above-mentioned skillsets (Kornelakis & Petrakaki, 2020). Overall, the findings reflect that our courses in the LS curriculum are embedded with active learning activities that offer good opportunities for developing HOT skills and GESA.

Table 3. Perceived “Good” and “Very Good” learning opportunities for developing GESA*.

Graduate Employability Skills and Attributes (GESA)@	**Percentage rated “Good” and “Very Good” opportunities within each level# (Number of LSM courses)**				**Percentage across all levels^ (n=90)**
	Level 1000 (n=4)	**Level 2000 (n=17)**	**Level 3000 (n=34)**	**Level 4000 (n=35)**	
Analytical & Critical Thinking	100%(4)	100%(17)	97%(33)	100%(35)	99%
Problem-solving & Decision-making	100%(4)	94%(16)	91%(31)	89%(31)	91%
Written Communication	75%(3)	65%(11)	91%(31)	89%(31)	84%
Interdisciplinary Thinking	100%(4)	65%(11)	79%(27)	91%(32)	82%
Collaboration & Teamwork	100%(4)	65%(11)	85%(29)	83%(29)	81%
Creative Thinking	100%(4)	71%(12)	74%(25)	89%(31)	80%
Adaptability & Learnability	100%(4)	65%(11)	76%(26)	89%(31)	80%
Verbal/Oral Communication	75%(3)	41%(7)	76%(26)	89%(31)	74%
Self-Efficacy	75%(3)	53%(9)	71%(24)	89%(31)	74%
Resilience	100%(4)	76%(13)	74%(25)	69%(24)	73%
Planning, Organising & Management skills	75%(3)	47%(8)	79%(27)	60%(21)	66%
Digital & Information Literacy	50%(2)	53%(9)	62%(21)	74%(26)	64%
Quantitative Thinking	25%(1)	76%(13)	65%(22)	63%(22)	64%
Ethics Awareness	75%(3)	24%(4)	65%(22)	57%(20)	54%

* Instruction: Please estimate and rate the opportunities for students to experience, practice, learn and develop the following skills and attributes based on the learning activities and assignments in the course (Likert scale 1=Very Poor; 2=Poor; 3=Average; 4=Good; 5=Very Good).

@ The list of GESA is derived from Lam & Ip (2018).

Percentage within each level is calculated based on the number of courses that were rated “Good” and “Very Good” divided by total number of courses within each level.

^ **Percentage across all levels** is calculated based on the total number of courses that were rated 'Good' and 'Very Good' divided by the total number (n=90) of across all levels.

Perceived learning of soft skills by DBS graduates and room for improvement

To further reflect on whether our students has benefited from those opportunities for developing HOT skills and GESA as perceived by the course coordinators, we examined the data of the perceived learning of soft skills by our DBS graduates reported in the Graduate Employment Survey (GES2022) conducted by the Singapore Ministry of Education in November 2022 which gathered the relevant data from graduates from local universities. The processed data representing DBS graduates (n=298) who responded to the survey were obtained from the Deanery Office, Faculty of Science, NUS. With respect to how well NUS education prepared (or equipped) them with the 10 soft skills listed in Table 4, only 38% to 67% rated "Well" and "Very Well". This suggests that there is room for improvement to increase the percentage of "Well" and "Very Well" categories.

Table 4. The extent of soft skills prepared by NUS education and experience based on DBS graduate's perception from Graduate Employability Survey 2022*.

Soft Skills	Percentage rated "Well" and "Very Well"
Interpersonal and Collaboration Skills	67%
Critical Thinking	65%
Curiosity and Independent Learning	65%
Communication and Engagement Skills	63%
Personal Values and Professional Ethics	63%
Digital Literacy	61%
Personal Effectiveness	60%
Multi-/interdisciplinary Knowledge and Skills	57%
Self-Awareness and Mental Resilience	57%
Innovation	38%

* Instruction: To what extent has your NUS education and experience prepared you in the following (soft skills) using the Likert scale: 1=Not At All; 2=A Little; 3=Fairly Well; 4=Well; 5=Very Good. Number of DBS graduates responded, *n*=298.

Survey performed in November 2022 by Ministry of Education, Singapore.

Data sourced from NUS Faculty of Science, Deanery Office.

Moreover, the perceived learning of the soft skills by DBS graduates (Table 4; from 38% to 67%), with the exception of "Personal values and Professional Ethics", was generally lower than the perceived learning opportunities of GESA by course coordinators (Table 3; from 54% to 99%) if we were to compare them indirectly using overlapping keywords with similar meaning. Assuming that greater opportunities for learning a skill will lead to better learning of the skill, this suggests that not all learning opportunities for GESA perceived by the course coordinators benefitted the learning of soft skills as perceived by their students. This could be due to the students not being aware of the opportunities or not being intellectually ready or motivated to learn those skills (Lam & Ip, 2018). It is also possible that the pedagogical approaches employed to train students in these skills were ineffective or that active learning failed due to student reluctance, instructors' beliefs on how these skills are acquired, and/or an environment that is not supportive for skills learning (Silverthorn, 2020). As for soft skills such as "Curiosity and Independent Learning" and "Innovation" (Table 4) that are not captured in our current findings (Table 3), we could include them in our future survey as they are best acquired through research-based courses in our LS curriculum such as the undergraduate research opportunity programme in science (UROPS) and final year (capstone) research project. Additionally, our courses should be regularly updated with information on frontier

research and cutting-edge technological applications, while students can be encouraged to attend research talks and industrial seminars to expose themselves to the latest developments and innovations.

In order to improve the learning of these skills, we need to create greater awareness on the importance of GESA and make the teaching and learning of these skills more explicit and intentional. For example, through appropriate workshops/platforms, such as faculty development programmes and course design, we could teach faculty members how to integrate the learning of GESA together with discipline-content knowledge by designing course assignments and team-based projects that require the application of relevant GESA. To make teaching explicit, the instructor could model specific GESA to students and provide instructional supports for developing these skills for students to practice them in the disciplinary context. This will connect the learning of GESA with the learning of content knowledge and demonstrate the relevance of GESA in a disciplinary context where the practice of GESA could affect performance. To make learning of GESA intentional, formative self-assessments with guided reflections of the learning process can be used for students to chart their own development of GESA. Ragonis et al. (2020) have shown that the use of guided reflection throughout various course assignments is effective in nurturing growing awareness and motivation among students in developing the soft skills. This is important because students need to be aware of the opportunities and be motivated to develop GESA in active learning activities embedded in our LS courses. To this end, we have developed instructional supports and worksheets for reflection to nurture GESA and have been providing them to our freshmen in DBS Learning workshop over the past two years with the hope that students will be more aware, motivated, and prepared to learn these skills when opportunities present themselves in the courses. Moreover, evaluation rubrics for HOT skills following Bloom's taxonomy (Krathwohl, 2002) and for specific GESA can be designed for teacher's use in formative evaluation and for student's self-evaluation as part of the strategies in making the teaching and learning of these skills explicit and intentional as well as to facilitate us to obtain direct evidence of the learning impact in future endeavour and study.

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ABOUT THE CORRESPONDING AUTHOR

Siew Hong LAM is an Associate Professor and teaches at the Department of Biological Sciences (DBS), Faculty of Science, National University of Singapore. He is currently the department's Assistant Head of the Undergraduate Matters and the Co-chair of the Department Teaching Committee. He is interested in creating rich environments for active learning and to equip future-ready graduates with transferable soft skills. He is working on the use of generative artificial intelligence (Gen AI) tools to enhance metacognition and academic confidence in students. He is also actively supporting the professional development of fellow educators.

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