Neither Schoolgirls nor Schoolboys but STEM Learners: Develop and Evaluate Training Course for Hong Kong Secondary School STEM Teachers to Cultivate Gender Equality in the Learning Environment: Case Study

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Abstract: *This case study developed and evaluated a 3-week training course with 3 weekly modules pedagogically rooted in Mezirow's transformative learning theory. The course aspired to reshape gender-related teaching concepts and practices of Hong Kong secondary school STEM teachers and eventually cultivate gender equality in 4 STEM teaching aspects that influenced female and male students' expectancy and task value of Eccles's situated expectancy-value theory. Gender equality here did not mean exploiting STEM learning opportunities for male students to put female students at an advantage. It aimed at freeing every STEM learner, regardless of gender, from traditionally stereotypical views on male and female STEM performance and ensuring equal multi-aspect learning access (Balan & Stanciu, 2021). The study purposively sampled 6 male and female first-year STEM teachers at different mainstream co-educational secondary schools to participate and qualitatively leveraged 2-stage semi-structured individual interviews: pre-training interviews on prior gender-related teaching concepts and post-training interviews to gather their voices on 1) whether and how this course reshaped their concepts and 2) practical improvements to support them further (i.e., 2 research questions) where thematic analysis ran. Participant teachers hugely reshaped gender-stereotypical concepts and practices through 3 essential transformative learning phases. It constructed 2 improvements: 1) further transformation of teachers' previous STEM schooling experiences and 2) reachable access to gender-balanced STEM role models (with QR codes).*

Keywords: Gender equality in STEM learning, Hong Kong secondary school teacher training, Situated expectancy-value theory, Mezirow's transformative learning theory

1. Introduction: the need of developing and evaluating gender equality teacher training course

"Boys should innately excel in STEM subjects as they can think logically!" "Girls are good at writing and should pursue art-related careers instead!". "Masculine STEM" and "feminine arts" teacher gender-stereotypical beliefs have long subsisted in multi-shapes and socially burdened two genders in STEM academic tasks and careers (Eccles & Wigfield, 2020). Maries et al. (2022) revealed that "boys-only" STEM clubs demotivated female students to sustain their STEM strengths. Makarova et al. (2019) echoed that underrepresentation of female STEM role models in secondary school textbooks added anxiety to female students' pursuit of STEM careers. The burden intensified in mainstream secondary education when Grade 9 students chose art-related or STEM-related electives of public examination. Physics topped, and ICT ranked fifth on the male elective choice chart. However, neither topped the six elective choices of female candidates who turned to more art-related fields, such as geography (EOC, 2022). Another turning point situated in Grade 12 when students arranged their university programme preferences that heavily illuminated relevant career options. Male students applying for STEM university programmes to pursue STEM career goals were twofold more than females, who occupied around 70% of humanistic caregiving sectors (EOC, 2022). PISA 2022, moreover, reported the widening gender gap in Hong Kong secondary school mathematics achievement, where female students underperformed male students by fifteen scores more in 4 years (Schleicher, 2023).

Gender-stereotypical teaching concepts seemingly favoured male students. Yet, overwhelmingly high expectations that boys innately excelled in STEM learning lowered the self-efficacy of low-performing male students and pressurized high-achieving ones (Zhang et al., 2022). It urged this study to develop and evaluate a well-polished training course to reshape Hong Kong secondary school STEM teachers' gender-related beliefs and practices to cultivate gender equality in STEM learning. Before so, it should investigate how secondary school STEM teachers' gender-related concepts and practices induced these students' gender struggles in STEM learning.

2. Background: from teachers' gender-related concepts to students' achievement motivation

Eccles's situated expectancy-value theory (hereafter SEVT) summarized two factors for STEM achievement motivation (Eccles & Wigfield, 2020). 1) Expectancy: student beliefs on how well they would accomplish STEM academic tasks. 2) Task value: tetra-dimensional value students derived from STEM academic tasks: intrinsic (how well tasks captivated students), attainment (student perceived significance of STEM task success), utility (usefulness of tasks for student prospective aspirations), and cost (how much inputs students had to devote for STEM academic tasks). In line with Bronfenbrenner's ecological systems theory, teacher socialization, which occupied the microsystem level, primarily and continually influenced student expectancy and task value. Students emotionally internalized and projected gender-associated treatments from STEM teachers onto the world's perceptions of genders in STEM fields (Bronfenbrenner, 1979). Pygmalion effect underlying teacher expectancy and self-fulfilling prophecy contextualized vicious STEM learning cycle: The less rigid the beliefs that acquired potential prioritized over inborn gender-based abilities to strive for STEM academic excellence a teacher held, the less frequent the constructive STEM teaching assets a teacher provided for the student gender group, the more reinforcing the false self-concept that efforts did not help their STEM accomplishment a student clung to, the worse STEM achievement that withheld students decisions to STEM further studies and careers and perpetuated teacher stereotypical gender beliefs a student enacted (Rosenthal, 2002). That said, mainstream teacher training focused on pedagogical knowledge (Makarova et al., 2019). Other cities' designs could not take over due to city-based differences in STEM learning curriculum and foci teaching aspects which teachers should act. This qualitative case study, therefore, aimed to develop and evaluate a 3-week teacher training course to empower Hong Kong secondary school STEM teachers to co-cultivate gender equality. The study addressed two research questions (hereafter RQs): RQ1) Did the teacher training course reshape STEM teacher concepts on cultivating gender equality in the learning environment? If so, how? RQ2) How could the training course be improved to support Hong Kong secondary school STEM teachers in cultivating gender equality in the learning environment?

3. Methodology: training course theoretical frameworks and qualitative data

3.1. Compound theoretical frameworks for 3-week training course content and pedagogy

The training content contextualized four teaching aspects impacting student expectancy and task value of SEVT, which mainstream secondary school STEM teachers should conceptualize and act to cultivate gender equality (Eccles & Wigfield, 2020). Teacher expectations implied in lesson materials (textbooks and tailor-made notes) showcasing STEM role models of two genders influenced student expectancy (Makarova et al., 2019). Three teaching aspects influenced student task value: 1) elective and career advice (STEM/Art stream), 2) student recruitment to and grouping in STEM workshops, and 3) attributions for STEM academic success and failure (Maries et al., 2022). Mezirow's transformative learning theory framed training pedagogies with three interdependent elemental changes that guided participant teachers to transform in these SEVT-embedded multi-teaching aspects (Spear & Costa, 2018). 1) Psychological change: participant teachers experienced unprecedented emotional ups and downs in the expectancy and task value when female and male students encountered teacher-led gender struggles. 2) Conviction change: participant teachers related them to daily STEM teaching and set their hearts on falsifying relevant gender-related beliefs and practices. 3) Behavioural change: teachers co-constructed new gender-related beliefs and practices in these teaching aspects and felt self-motivated to enact. Contextualizing the elemental changes, each of the three transformative phases in Appendix 1

pedagogically supported one sequential training module. Fleming (2018) unveiled the feasibility of transformative learning over lecture-based instruction to cultivate educational gender equality. STEM teachers acted as active minds-on and hands-on engagers rather than passive receivers who rejected changes because of "valid" deep-seated gender-related misbeliefs and short-term memory to sustain. The course held three 90-minute tailormade weekly modules in April. Appendix 2 described how SEVT and Mezirow's transformative phase complementarily guided three subsequent module activities.

3.2. Qualitative data collection and analysis

The study purposively sampled 3 female and 3 male first-year STEM teachers to join and evaluate training. As all have organized diversified STEM activities at different Hong Kong co-educational secondary schools and had no prior exposure to gender-related training courses, they could authentically visualize how their transformed practices influenced students' expectancy and task value at the earliest year of service and extend evaluation of transformative effectiveness to prolongedly unexplored gender-related concepts (Tang et al., 2021). Equal gender proportion removed selection bias, enabling male and female teachers of different prior gender-related STEM schooling experiences to bring refreshing insights. Codes (Female Teachers: FT1, FT2, FT3; Male Teachers: MT1, MT2, MT3) were assigned to preserve anonymity. Individual semi-structured post-training interviews (compared to pre-training interviews) elicited participant teachers' personalized changes in gender-related beliefs and practices in four SEVT-embedded teaching aspects and how each transformative learning phase facilitated changes to answer RQ1 (Fleming, 2018). They also probed into practical improvements in training content and pedagogies to answer RQ2. Thematic analysis ran on transcribed interview data to deduce theoretically grounded codes.

4. Results, findings and discussion

The following first answered RQ1, which focused on twofold theoretical evaluations: 1) "Did"- evaluating the effectiveness of SEVT-embedded training content on transformed teachers' gender-related concepts and practices influencing students' expectancy and task value, and 2) "How"- evaluating the effectiveness of Mezirow's transformative learning training phase to call forth corresponding transformations.

4.1. Transformative gender-related concepts influencing students' expectancy in STEM learning

It evaluated effectiveness of SEVT-embedded training content in module 1 to transform gender-related concepts and practices in teaching aspect of lesson materials (textbooks and tailor-made notes) influencing expectancy of SEVT and the corresponding transformative phase "disorienting dilemma and critical assessment" to bring about the transformation.

4.1.1. Effectiveness of SEVT-embedded training content

Almost all participant teachers were shocked by male-dominating STEM role models in textbook extracts (excluding FT2, who already noticed) (sample theme categorization in Appendix 3). MT2 realized, "It is out of my expectations that many male scientists appear in the science textbooks" and strived for gender-balanced representations masked by prior foci on teaching content. Remarkably, FT3, who previously justified gender equality in STEM textbooks by the scarcity of field-specific female scientists, recognized that gender-unbalanced issues existed in general textbook topics and devised an alternative of exemplifying herself in the STEM field to include female STEM contributions in elevating female students' expectancy to succeed in STEM. Moreover, all participant teachers revealed their post-training willingness to balance but not overwhelm role models of two genders in STEM lesson notes so that students could mirror themselves in STEM careers. MT1, who priorly selected three male scientists to include in his tailor-made STEM teaching notes, proposed how he would balance the gender representations in the forthcoming STEM teaching chapter, "When I teach about DNA structures, I can introduce students to Franklin's (a female scientist) photo 51." Extensively, FT1 put her transformed ideas of gender-balanced notes into practice, recalling, "Towards the end of the academic year, I am trying to incorporate more examples of female scientists into learning worksheets to inform students that aside from male scientists, female students can also contribute to STEM."

Participant teachers learned why they should change in bid for students' expectancy and STEM achievement motivation. FT1 recognized, "If teacher expectations are without gender bias, male and female students will believe they can really perform well in STEM-related subjects (expectancy), work harder for better STEM results, and solve problems actively." FT2 and MT3 grasped magnifying influence of teacher expectations on secondary school students' expectancy at Erikson's "identity versus roles" stage that the course selectively targeted, "It is essential to manage our expectations on students who are still exploring whether they can do something, no matter STEAM or not." (Erikson, 1950)

4.1.2. Effectiveness of Mezirow's transformative learning pedagogy

Nearly all participant teachers (excluding MT3) agreed that "triggered emotional struggles" and "self-assessed similarity in teaching" facilitated the abovementioned changes (sample theme categorization in Appendix 4). Given extracts effectively triggered MT1 and MT2 emotional struggles of resonating with female students' "dilemma" of seeing themselves and sustaining expectancy in STEM careers under overwhelming teacher male-dominated lesson materials and motivated them to watch out for textbook gender-imbalance and balance gender representations in lesson notes. FT1 echoed, "Textbook extracts surprised me a lot because I didn't pay much attention to the gender of scientists. Teachers need to amend some teaching notes and add more examples of female scientists," which facilitated her above practices of amending gender-balanced STEM lesson notes. FT3 and FT2 recognized that constrained lesson preparation time induced her slothfulness in recalling and searching for female scientists. "Because of time constraints during lesson preparations, we will follow the textbooks and suggestions from the curriculum." "Critical assessment" with textbook extracts acknowledged the importance of real-life practice on top of on-paper awareness to elevate expectancy.

These sections revealed that expectancy-embedded content in module 1 hugely empowered participant teachers' transformation of gender-related concepts and practices in lesson materials through the first Mezirow learning phase to cultivate gender equality. Some found textbook extracts engaged them unprecedentedly in students' frustrations to stay in STEM fields with gender-unbalanced representations of STEM role models (anchoring to "disorienting dilemma"). Affective struggles alerted them not to place the same burden on their students and falsify their previous and even inconspicuous real-life teaching concepts and practices (anchoring to "critical assessment") (Fleming, 2018). Some, therefore, became aware of gender-unbalanced role models in mainstream STEM textbooks and strived for more gender-balanced STEM representations in their tailor-made notes of forthcoming chapters. With this transformation, female students, who long-lastingly saw themselves as under-represented in STEM fields, could visualize females' remarkable STEM contributions and revitalize the expectancy of believing their potential contribution to STEM careers. It also helped male students recognize female STEM contributions and detach their gender stereotypes to extend peer-level gender equality in STEM learning (Becker & Nilsson, 2021).

4.2. Transformative gender-related concepts influencing students' task value in STEM learning

It evaluated the effectiveness of SEVT-embedded training content in module 2 to transform gender-related concepts and practices in three teaching aspects of elective and career advice (STEM/Art stream), student recruitment to and grouping in STEM workshops, and attributions for STEM academic success and failure influencing task value and the transformative phase "acquisition of new knowledge and provisional trying of roles" to bring about the transformation.

4.2.1. Effectiveness of SEVT-embedded training content

After the training, FT1, MT1, and MT2 transformed from gender-based to ability/interest-based elective and career advice. MT1 recognized his flawed interest-based advice, "Although I previously claimed that students should take what they want for high school subjects, I tried to push boys to choose STEM-related subjects and girls to opt for non-STEM subjects. I should not have done that." Meanwhile, FT2, FT3, and MT3 saw training course reinforcing their practices in giving ability-/interests-based advice to maintain the STEM task value of female and male students. FT2 added, "As long as students like to participate in STEM, they do not have to make a stunning contribution. They can

still play their roles in STEM and practice STEM in daily life.", respecting students' interests rather than focusing on student genders to elevate students', regardless of gender, the utility value of daily STEM tasks.

MT2 and FT1, who previously recruited male students to STEM workshops first, transformed to open opportunities for two genders to receive equal teacher attention and resources at extracurricular STEM workshops. FT1 proposed how she could maintain equality: "Ask students to raise their hands and join the programme instead." Nearly all (except FT3) participant teachers transformed from gender-based to gender-free roles in heterogeneous grouping during workshops, including rotatory roles (MT3), "For this time, we assign presentation roles to male students. Next time, we ask female students to be responsible for the presentation. We give both the chance to taste different roles in STEM learning." and performance-based roles (FT2), "the role of proofreading or logical thinking should not be limited to genders, but rather their strengths." to sustain cost and attainment value of both genders.

FT1 and MT3 transformed from gender-dependent to gender-free attribution for success and failure, while MT1, FT2, and FT3 formed a more rigid one. FT1 saw the importance of regular positive reinforcement to recognize achievement (high attainment)/effort (for low performance) to revitalize STEM task value and sustain achievement motivation. MT3 freed his attribution from gender labels undermining task value, "Two student genders can achieve the same if they receive the same. We should not link gender to success or failure in STEM tasks."

Participant teachers internalized transformation conducive to elevated task value of both genders. MT2 saw teacher soundless gender practices mattered, " When teachers agree (implied in these teaching aspects) that gender matters most in STEM-related subjects, students will reject to choose STEAM-related subjects." FT3 added, "Everyone should have chances to engage. That's what gender equality looks like (aligning to true gender equality the course emphasized)."

4.2.2. Effectiveness of Mezirow's transformative learning pedagogy

Participant teachers concurred that "provisional trying of roles" underlying board game facilitated above transformation in task value. FT2 foresaw STEM pursuits at the end of secondary education (game endpoint) that gender mattered more than ability from student perspectives and transformed to assign performance-based roles in STEM workshops. "High-performing male students have a teacher-led shortcut to higher STEM achievement goals. It widens our horizon to probe into gender stereotypes behind this unfairness." MT3 additionally enlightened teacher role in gender equality through board game results, "If teachers had provided enough chance for both genders, they could have achieved the same goal." MT1, who recognized he should not push low-performing male students to choose STEM, added that immersive forward and backward movements of each student character, which simulated ups and downs in task value due to different teacher-led gender privileges and challenges, reminded him of overlooking pressure on male students and hence low intrinsic value with over-pronounced masculine stunning STEM achievement. FT1 further exemplified, "A challenge card was about teacher's blame on a low-performing male student who then had lower motivation to learn and STEM results. It reminds me not to blame their gender to think logically but to concentrate on their interests," where "trying of roles" explained FT1's above transformation in praising every student rather than attributing failure to gender.

FT1, FT3, and MT3 acknowledged fake gender equality practices (acquisition of new knowledge) that this training course intentionally added. They recognized that pull-out female STEM programmes, which aimed to promote gender equality, exploited male students' participation. They moreover saw similarities between gender equality practices and daily STEM teaching. FT1, who acted as a high-ability male student rejected from pull-out female programmes, felt the unfairness of gender-based student recruitment to STEM workshops. FT2 recognized unnoticeable gender-biased teaching practices undermining male students' task value, "I paid more attention to girls and helped them solve problems. I realize that when I gave such special treatment to girls, I ignored the boys. I do not solve gender inequality."

The two sections manifested that task value-embedded content in module 2 hugely supported participant teachers' gender-related transformation in three teaching aspects through the second learning phase to cultivate gender equality. Tailor-made board game anchored closely to "provisional trying of roles" where role-taking along the board game journey helped teachers experience fluctuations in task value of Hong Kong female and male secondary school students

under teacher-led opportunities and challenges to pursue STEM studies and careers (Fleming, 2018). They could project commonness from games (including teacher-led struggles and game results that high-ability male students usually edged out in STEM future) into their daily STEM teaching to raise abovementioned transformation (Fleming, 2018). Participant teachers moreover saw "acquisition of new knowledge" in not only how their gender-related practices influenced students' task value aside from expectancy but also fake gender equality. Balan and Stanciu (2021) unveiled that worldwide practices of including 'A' in STEAM, which intentionally increased female students' STEM interests, indeed intensified gender inequality, making feminine arts appealing to female students. Board games, therefore, exemplified fake gender inequality (pull-out female STEM programmes) prevalent in Hong Kong, which effectively reminded participant teachers of true gender equality and its applicability to daily practices (balanced FT2 attention on males).

With these transformative processes, transformation to ability-/interest-based teacher elective and career advice fortified female students' utility value on STEM tasks to transfer knowledge for future career choices and male students' intrinsic value to retain with genuine enjoyment (Zhang et al., 2022). Its importance amplified in Hong Kong secondary education to prevent post-secondary dislocation of female students aspiring in STEM to arts while male students aspiring in arts to STEM fields (Zhang et al., 2022). Transformation to academic-/interest-based student recruitment to STEM workshops of extensive teacher resources and attention increased the intrinsic, cost, and attainment value of female students who received equal teacher scaffolds (Maries et al., 2022). Transformation to gender-free roles in heterogeneous grouping revitalized female students' attainment and utility value in seeing their achievement for group success and male students' intrinsic value to take preferred roles in STEAM tasks (Maries et al., 2022). Transformation to gender-free attribution for success and failure (success of high-performing female students and failure of low-performing males were not due to uncontrollable and unchangeable luck and gender, as per attribution theory) enabled students to see cost value behind devoting effort and attainment value from teacher recognition (Weiner, 1985).

4.3. Effectiveness of last transformative phase-"building self-efficacy"

All participant teachers saw that "working together added confidence." FT3, who struggled between gender equality and teaching efficiency, saw this course as networking support for her difficulties. FT1 moreover unveiled the usefulness of scenario cards with critical gender-related incidents of Hong Kong Grade 7-12 students (e.g., taking electives, choosing undergraduate programmes) to put transformation into practice, "We had scenario cards and discussed how we could prevent this scenario at very beginning or what we should not do in the future. My groupmates gave lots of useful suggestions." FT2 exemplified how collaborative discussions reinforced her confidence in believing in students' uniqueness, "Being a teacher in one school limits knowing the strengths of students. With other participants, we can argue for gender stereotyping that boys may not excel in STEM subjects, and girls can also do very well." These together showed that collaborative groups in module 3 hugely boosted participant teachers' self-efficacy to put gender-related concepts and practices influencing expectancy and task value into authentic teaching from collective teachers' perspectives with scenario cards specific to the Hong Kong context. The uplifted self-efficacy sustained their beliefs, preventions, and solutions in cultivating gender equality in balance with teaching efficiency (Tang et al., 2021).

4.4. Improvements for training content and pedagogy

Although SEVT-embedded training course content and pedagogy rooted in Mezirow's transformative learning guided participant teachers to transform majoritively in the abovementioned teaching aspects, an implicit improvement (interpreted from participant interviews) for SEVT-embedded training content and an explicit improvement (direct suggestions from participants) for transformative pedagogy were necessary to add practicality into paperwork theories with participants' real-life STEM teaching experiences for further empowerment of gender equality (RQ2).

4.4.1. Implicit improvement on SEVT-embedded training content: further transformation of teacher prior STEM schooling experiences

MT1's post-training attribution, "male students may naturally have mathematical sense, but female students' effort can help." might still undermine task value of female and low-performing male students in seeing themselves at

comparatively inferior STEM starting points. He explained, “When I was in secondary school, boys had higher academic achievement in STEM-related subjects.” Some teachers projected previous self- and peer- gender-associated STEM performance (their gender-associated struggles, the big picture of gender achievement differences, gender ratio in STEM classes) to their students (Tang et al., 2021). MT1, who generalized gender performance in previous STEM classrooms and formulated parallel gender-related expectations on their students, overlooked STEM potential of female students. Misbeliefs could also form from socialization of former teachers. When they were students, their teachers unconsciously developed their gender-based expectancy and task value (Dinh & Nguyen, 2019). When they became STEM teachers, they exerted reinforced gender-related beliefs and practices on their students whose gender-based expectancy and task value needlessly went up and down. When the cycle perpetuated, teacher-led gender struggles formed more complex ties for future cohorts (Dinh & Nguyen, 2019). Training content should have linked them aside from current teaching to teacher-led gender struggles. Participant teachers should discuss guiding questions in Appendix 5 that probed into their previous STEM schooling experiences right after each board game movement in module 2 for substantial gender equality.

4.4.2. Explicit improvement on transformative learning training pedagogy: Reachable access to gender-balanced STEM role models

FT2 was aware of gender-unbalanced STEM role models in textbooks yet was slothful for balanced representations in her teaching notes due to “time constraints during lesson preparations.” Reachable access to gender-balanced STEM role models would help solve time constraints, encouraging her to put gender-balanced concepts into real-life practices and strengthening the transformative phase of “building self-efficacy.” MT3 saw the potential of accessible technology (QR codes) for extensive gender equality as some teachers in other schools had little exposure to topic-specific contributions of female scientists, “we can share with teachers at other schools. They will not be limited to very famous scientists in new topics.” Becker and Nilsson (2021) echoed twofold reasons for teachers’ gender-unbalanced representation in STEM lesson materials. First was little knowledge about less well-known topic-specific female scientists (like FT3). Second was adhesion to commonly used textbooks, which saved their lesson preparation time (like FT2) but stood in contrast to “building self-efficacy” that devised gender-related practices should be actualized. QR codes for gender-balanced STEM role models of different STEM chapters of Hong Kong curriculum (sample in Appendix 6) therefore leveraged handy technology to save participant teachers’ efforts and time for accessing less well-known scientists, motivate them to put gender-balanced STEM role models into lesson notes and share with their colleagues to cultivate gender equality at teacher networking level (MT3 suggested) and secondarily peer level which falsified expectations of masculine STEM contributions among peers (Becker & Nilsson, 2021).

5. Conclusion: prospective gender equality in the future

In sum, the tailor-made teacher training course largely reshaped gender-stereotypical concepts and practices influencing the expectancy and task value of SEVT of first-year participant STEM teachers serving at Hong Kong co-educational secondary schools through three Mezirow’s transformative learning phases. It constructed two improvements: 1) further transformation of teachers’ previous STEM schooling experiences and 2) reachable access to gender-balanced STEM role models (with QR codes). Despite limited resources, it hopefully brightened future course directions on co-cultivating gender equality at peer levels (i.e., students are under heavy peer pressure to stay in “unexpected” streams), such that Hong Kong students in current and future cohorts can take off socializing gender lens (schoolboys or schoolgirls) to perceive themselves simply as STEM learners and enter aspiring career streams, as the case study title suggested.

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Appendices

https://drive.google.com/file/d/149-bot4pqlSmNOteb14IAkdDn9b29Syq/view?usp=sharing