AN INNOVATIVE SCIENCE AND TECHNOLOGY EDUCATION PROGRAM EVALUATION STUDY IN THE HIGH SCOPE PLAN

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รับต้นฉบับ 8 ก.ค. 62 ปรับแก้ไขตามข้อเสนอแนะของผู้ทรงคุณวุฒิ 15 ธ.ค. 62 ลงตีพิมพ์ 20 ธ.ค. 62

ABSTRACT

This program evaluation study aims to evaluate one of the "High Scope Plan" (HSP) programs from the academic year 2011-2014. HSP policy supported by Taiwan Ministry of Science and Technology (MOST) tended to conduct several school-college collaborations and deregulation to develop innovative science and technology curriculum. This program evaluation study used testing, observation, focus groups, and interviews. In this HSP program, the chemistry class looked into bioenergy issue while the biology class looked into environmental tourism. This study showed: 1. The HSP policy launches the "school-college collaboration" can support STEM education. 2. Proper funding and deregulation can benefit Science, Technology, Engineering, and Mathematics (STEM) education, especially developing innovative curriculum. 3. For teachers, using alternative evaluation can be inclusive and supportive.

Keywords: Program evaluation; High Scope Plan; Educational policy; Science education; Alternative evaluation

Introduction

This study evaluated the performances and implications of one of the "High Scope Plan" (HSP) programs from the Republic of China (Taiwan). The HSP policy implements school-college collaboration and deregulation supporting innovative science education programs. Many policymakers consider Science, Technology, Engineering, and Mathematics (STEM) capacity as an important foundation for overall economic or innovative development. The United Nations Educational, Scientific, and Cultural Organization (UNESCO) stated the *Perth Declaration on Science and Technology Education* (2007) to address strong concern about the state of science and technology education globally, and it also called on governments to respond to UNESCO suggestions to establish the structural conditions for improving their science and technology practice (Fensham, 2008; UNESCO, 2007). Education can be considered as the foundation for developing STEM capacity. Therefore, educational governors and researchers are trying various ways to improve STEM education optimization. The result of this study may serve for future science educational policymaking.

Policymakers usually consider science and technology education as an important issue relating to the future human resource and national development. OECD (2012) reported among high-performing countries had good advice and guidance in a school system along with the quality of career guidance is crucial to effective skills policies. It is important to inform or alert young people about the changing job market and future opportunities (Falk et al., 2015). It is also predicted the growing 8.9% for STEM labor force needed between 2014 and 2024 in the U.S. (ACT, 2017). Therefore, STEM education is important to motivate students to choose STEM majors and careers meeting the future market needs.

There is an increasing need to improve STEM education quality and increase students interested in STEM majors. This program evaluation study intends to provide an example of a science education program from Taiwan. Taiwan has performed quite well in STEM education. In the "Programme for International Student Assessment" (PISA) 2015, Taiwan ranked 2 for upper rank and ranked 7 for lower rank in science performance (OECD, 2016a). However, Taiwan government is still expecting to increase STEM education and labor forces. Therefore, besides the original science education standards, Taiwan carries out the HSP policy as an initiative policy to develop innovative STEM curriculum.

There are two main characteristics of the HSP different from many other educational innovation policies in Taiwan. One is directly supporting collaboration between a middle school and a university; another one is deregulation that supports innovative activities. The HSP policy is the first time that National Science Council (NSC, later reformed became the Ministry of Science and Technology, MOST, in 2014) gives funding directly to teachers and schools to support school-college collaborations (NSC, 2009). There used to have limited collaboration between a middle school and a university in Taiwan. The HSP policy provides the opportunity for a secondary education school to work with a higher education institution to develop the curriculum that focuses on innovative scientific or technological issues. Some studies showed school-college collaboration might lead to positive outcomes (Kramer-Vida, Levitt & Kelly, 2012). HSP policy expects to have rewarding outcomes from school-college collaborations. Through school-college collaborations, the HSP policy expects schools can get resources from the college to conduct curriculums that not only emphasize scientific and technological issues but also become innovative ones beyond regular school curriculums. The final goal of the HSP policy is to develop some innovative curriculum models that other schools can use.

The second characteristic of the HSP is deregulating that encourages innovation and creativity in school settings. Taiwan Ministry of Education has some regulations for curriculum while schools also have pressure to meet the official learning schedule. Teachers have to teach according to the tide schedule with limited time to conduct extra learning activities beyond textbooks and formal learning goals. In order to encourage innovative curriculum, the HSP policy offers the opportunity for deregulation and openness to conduct curriculum development. HSP programs allow curriculum designs to go beyond official regulations with more flexibility in curriculum arrangement. HSP programs also open to using various curriculum designs and teaching methods that differed from regular school settings. Teachers could design and arrange class activities based on their professional judgment, such as class time, where to do learning activities, and setting their own learning goals instead of following school official learning goals. Therefore, the objectives of this article focused on evaluation HSP program and implementation of HSP policy, the following research questions are:

1. What are the influences of school-college collaboration?
2. What are the influences of the deregulation of curriculum?
3. What kind of evaluation approaches can support teachers?

This study not only concerns the accountability (as the evaluating HSP program outcome) but also offers insights for future policy considerations. This study provides a case showing school-college collaboration and deregulations can support innovative science education. Moreover, using alternative evaluation can encourage inclusive participants and program improvement. Future science education policymakers may set policies based on this study to conduct innovative science education.

This HSP is a three-years round program starting the academic year of 2011 to 2014. In the academic year of 2013, the HSP program team members became more experienced while the program became more mature. Therefore, this article mainly focuses on its program evaluation outcomes of the third academic year.

Prior Studies

1. Science educational policy

Educational policymakers should consider the influence of middle school students to have science education. The UK study showed approximately 50% of young people who were aspirated at age 15 will eventually take similar occupations 10-15 years later (Croll, 2008; Falk et al., 2015). Moreover, 14 years old adolescents in the U.S. who have the aspiration to science are about 3.4 times more likely to pursue physical sciences or engineering degree (Falk et al., 2015; Tai et al., 2006). There is a potentially negative result from a disadvantaged background that aspires highly but lack of academic attainment and resources to achieve their goals (Falk et al., 2015). In the U.S., a study indicated inclusive STEM high schools (ISHSs) may not necessarily improve students' test scores, but they may improve the rates of high school graduation for racial minority and low-income students (Saw, 2019). Educational policy should consider raising aspiration, even "diversifying" and "informing" aspirations, so that all young people, including disadvantaged ones, can achieve interesting and well-paid jobs in the future (Falk et al., 2015). The Organisation for Economic Co-operation and Development (OECD)(2016a) stated that what happened in the classroom is crucial for students regarding their learning and career expectations. Science and technology education can increase students to choose and encourage them to relevant careers.

K12 and higher education can collaborate to learn from each other to enhance student learning (AAHE, 1993). Science education may take advantage of school-college collaboration to encourage students to understand and choose a STEM major in the future. A study also showed a positive attitude and greater knowledge were indirectly associated with higher perceived behavioral control and subjective norms that were also associated with stronger STEM teaching intention among preservice science teachers (Lin & Williams, 2016). It also supports collaborative curriculum development that benefits science education.

As to deregulation, OECD (2016b) claimed that schools having more autonomy with flexibility could respond to local students' needs might have higher science scores. The deregulation is to offer science education to have the opportunities to go beyond regular curriculum and school settings. This offers teachers to teach some cutting-edge issues in science classes and develop a more innovative curriculum to improve the quality of STEM education and inspire students.

2. Alternative evaluation

The program assessment or evaluation is considered as means to respond to accountability. Some asserted evaluators should also evaluate how learners think and their thinking changes in educational program evaluation instead of merely performance (Micari, Light, Calkins & Streitwieser, 2007). In our HSP program, the teachers were highly empathizing with students to learn science to higher knowledge skills and increase scientific interests. Both teachers used multiple ways to evaluate students' learning, including learning sheets, tasks, and observation. School administrators were able to understand teachers' concerns and were supporting teachers' assessment ideas through the HSP program's monthly meetings.

This HSP program evaluation design used alternative evaluation approaches to a better understanding of this HSP program. The main alternative evaluation approaches in our HSP program was participatory evaluation approaches. Participatory evaluation invites stakeholders as partners to conduct the evaluation (Cousins & Earl, 1992; King, 2005; King, 2007). There are several principles for participatory evaluation, namely, democracy, inclusion, dialogue, deliberation, and mutual accountability (Fitzpatrick, Sanders, & Worthen, 2011; Samuels & Ryan, 2011). The HSP program invited stakeholders to involve in collecting and analyzing data as well as generating recommendations for program improvements. According to Ryan, Chandler, and Samuels (2007), schools may systematically use various forms of data to express teaching and learning when schools think evaluative way. The HSP team members discussed to defend the value of this curriculum was not merely the outcome of the experiments and test scores, but rather their motivation in learning science and problem-solving ability.

In the meetings, teachers participated in setting criteria for evaluation and determined students' performance assessments. The formative evaluation outcomes were shared with the stakeholders in our HSP meetings so that the HSP team could discuss and adjust our HSP program. Teachers' concerns were included in evaluation designs and shaped this program evaluation process. The evaluation focused more on students' motivation and improving science capacity rather than merely test scores. By using participatory evaluation, the teachers also responded they were more willing to involve in evaluation than objective – oriented evaluation.

Data and methods

1. Program backgrounds

Since 2006, Taiwan NSC launched the HSP policy to encourage middle schools to establish a partnership with universities to conduct innovative science or technology curriculums. The HSP policy preliminary aims to improve high schools and vocational schools' science education quality (NSC, 2009). The HSP policy has the main purpose to develop some innovative curriculum models so that other schools can adopt. It empathizes on integrating innovative science or technology issues into the school curriculum. In the early stage of the HSP policy, it only included high schools or vocational schools. Since 2011, NSC has launched the second round of HSP programs to extend partnership to junior high schools.

The second round started in the academic year of 2011 and supported multiple assessments with more schools participating in HSP (NSC, 2013). The second round of the HSP also encourages schools to design science and technology issues into regular courses and encourage schools from the rural area, indigenous regions, or underrepresented students to join HSP programs (NSC, 2013).

There were two classes that participated in this HSP program focused on chemistry or on biology respectively. This HSP program tried to resolve the carbon dioxide problem and environmental protection issues. Each year, only high school freshmen were selected to enroll in the HSP program. After students became sophomores or seniors, they were no longer participants in our HSP program.

In the 2013 academic year, two teachers were invited to participate in this HSP program. There were two small- size classes in our HSP program. This HSP program was not required courses so that students would choose to participate based on their own interests. However, students who were showing potential talent or special interests in science were encouraged to enroll in these two classes by the teachers. Each week the teachers and the students met for two hours as formal courses and met additionally during their lunch rest time or after school when needed. They arranged professors to give several lectures and visit university laboratories. These students also got the chance to go to the National Science Museum to attend external lectures from experts. The funding for HSP also supported them in field trips included an industrial institution developing bioenergy study and other environmental tourism parks.

The chemistry class looked into the bioenergy issue by using alga. Students designed containers to raise alga and tried to understand how to transform alga into other energetic resources. This experimental class was quite challenging for both the teacher and the students. First, they had limited background knowledge for cultivating alga. Therefore, they needed to conduct literature reviews and consulted other professors and experts to explore possibilities to cultivate alga. They came up with several possible solutions to increase the amount cultivate of alga. Second, another challenge was how to transform alga into a useful energy resource. According to some literature, alga can be extracted to provide biomass, but it is still quite hard and lack of efficiency to do so. Therefore, even some large research institutions encounter challenges. However, the teacher and professors had discussed and considered alga as a good starting example for students to understand bioenergy. The teacher and students in this class were trying to find creative ways to overcome experimental challenges.

The biology class was combining tourism and environmental issues. The teacher and the students were analyzing carbon dioxide in a different area to understand the influences of human activities in natural surroundings, especially in the local area, such as their own high school. They also needed to understand more about how to measure carbon dioxide, how it might influence the surroundings, and how to cooperate with these influences with tourism ideas. The main challenges included students were lack of the theoretical backgrounds of how carbon dioxide influences and how to design meaningful tourism projects. The teacher and the students in this class were going through literature and discussions to gain creative ideas to achieve their goals.

Both classes had invited professors and experts to give lectures sharing their professional perspectives. Both teachers used the group teaching strategy to put students into groups for creative problem-solving. HSP team arranged several professional speeches to increase professional knowledge. They also visited the National Science Museum to have experts teach them progressive science knowledge.

2. Evaluation data and collection methods

The data collection of this evaluation program used various methods, including observation, surveys, interviews, focus groups, tests, and portfolios. This program evaluation used observations were recorded and analyzed to assist the understanding of how teachers and students interacted and behaved. It also helps to gain qualitative data to judge how students performed in group discussions, problem-solving, and doing experiments. Observations may help both teachers and evaluators to understand students' behaviors and how teachers influenced the classes. The observation data was recorded and discussed with teachers. This also uses an observation sheet to remind the evaluator and focus on certain learning behavior, such as responding to questions, experiment operations procedure, and taking notes.

This HSP program conducted the survey with multiple choices and a few open-ended questions regarding their learning experience in this curriculum. Students can express their thoughts in the survey. The survey can offer the HSP team how students were doing in the class.

This evaluation also used interviews and focus groups every semester to gain meaningful insights from participants. The questions for conducting surveys, interviews, and focus groups were developed based on literature and discussions within our HSP team. The interviews and focus groups were recorded and made transcripts. The interviews and focus groups mainly helped to understand what did students experience in the program. The results were shared in our HSP team meetings. HSP could adjust the curriculum design and teaching methods based on the feedback from the interviews and focus groups.

For evaluating students' learning outcomes, tests provided a way to assess subjects' knowledge and capacity. This HSP program evaluation used both tests and multiple assessments to evaluate students' learning outcomes. In addition to teachers' design in-class tests, this HSP program also used the "basic science literacy" (Taiwan) (Chin, 2002) to test and compare their learning outcomes. The test outcome had to be analyzed and discussed with teachers.

Evaluation design also used participatory evaluation that took much time to understand the program context, stakeholders, and encourage participating. Evaluators conducted observations and interviews to gain more understanding from stakeholders. Both teachers not only concerned about test results but students' motivation and creativity. Standardized science tests have limitations; they may not be able to measure students' rational powers (Morgenstern & Renner, 1984). STEM education may need to use multiple ways of assessment and evaluation (Lawrenz, Huffman, & Thomas, 2006). Therefore, this program evaluation also used multiple assessments to gain a better understanding of students' overall learning outcomes. Two teachers measured learning outcomes and attitudes by group problem-solving tasks, debate activities, learning sheets, and portfolios. Students were evaluated through multiple assessments based on teachers' professional judgments. Teachers and evaluators also looked into portfolios and understand how students' learning progress in the HSP program.

3. Evaluation study outcomes

There are three main evaluation study outcomes. First, this HSP program showed school-college collaboration works. Second, students in this HSP program showed increasing interests and improvements. Third, teachers encountered stress but overcame due to using alternative evaluation approaches.

3.1 School-college collaboration

The HSP policy offers the opportunity for school-college collaboration to conduct innovative curriculum. According to our HSP program's design and observation field notes, this HSP program met the school-college collaboration initiatives as what Cuseo (no date) claimed. This HSP program increased the beneficial partnership between a school and a college. First, students responded they learned a lot from the professors' speeches. From the 2013 survey, 80% of the participated students were highly agreed or agreed that they learned a lot from the HSP program. Second, students were able to see how to conduct professional experiments in university laboratories and had the chance to understand what it might be like to be a college student. Third, professors who participated in the HSP program also had the chance to meet these potential college students. Professors said they had a good time interacting with the students in the meeting. Fourth, HSP arranged meetings so that high school teachers got the chance to interact with professors and colleagues. This sort of collaboration offered the chance for teachers to conduct their professional development.

Professors from the chemistry and biology departments had the chance to discuss with the teachers to develop the curriculum. Teachers were given some newest research papers and the professors also shared their experimental experience. Teachers also responded interacting with professors was helpful when developing curriculum and teaching. HSP program showed positive school-college collaboration that benefited participants.

3.2 Students' improvement

As to students' improvement, evaluation outcomes also identified students' positive responses to attending the HSP program. First, their attitude of doing experiments and awareness of environmental protection has changed. From the 2013 survey, 72% of the student body indicated that they were more aware of the environmental protection issues. Moreover, 76% of the student body said they were willing to join the program if they were chosen again. No one responded that they were regrets participating in the HSP program.

Student 1: (we) will recommend other students to join the project.

Second, their problem solving and science capacity improved. In-class observations and teachers' observations feedbacks showed many students were interested in doing science experiments. Students responded they would like to have more time doing experiments in the focus group. They also responded that they were able to learn more about carbon reduction and environmental protection issues in the focus group after attending this HSP program.

Student 4: (we) learned a lot of science and be aware of things that we used to ignore (carbon reduction)

There were total of 28 freshmen enrolled in this HSP program in the 2013 academic year. The test used science literacy comparing to the other 25 students from another normal class showed a significant difference in Table 1.

Table 1 Third year students' science capacity performance comparing to other students.

Group	N	Sum	Average	ANOVA
HSP students	28	2509	89.607	70.914
Others	23	1839	79.957	158.953

ANOVA

	SS	df	MS	F	P-value
Between	1176.051	1	1176.051	10.649	0.00**
Within	5411.635	49	110.442		
Total	6587.686	50			

$^{**}P<.01$

Professors and reading materials offered theoretical knowledge that helped to build up participants' science capacity. Additionally, some students responded their presentation skills and data analysis skills were also improved. Teachers also confirmed students had improved their presentation and statistic skills.

From the assessment sheets, in- class observations, and teachers' feedbacks showed most students had increased in science knowledge, motivations and experimental skills. One of the most obvious improvements was problem-solving ability. For example, students designed the photosynthesis device to raise alga or how to measure CO_2 faced some challenges. In total three years of this HSP program, from teachers' assessments and project presentations, the qualities of either alga photosynthesis or eco- tourism designs were also increasing. Table 2 showed our HSP program outcomes within a total of three academic years. In the 2013 academic year, teachers and evaluators could observe students in chemistry class used innovative ways solving problems of alga photosynthesis design and cultivating alga. In the biology class, some students also came up with some interesting ways to design eco-tourism plans.

Table 2 Three years of HSP outcomes.

	2011-2012	2012-2013	2013-2014
Chemistry	1 air reaction machine	3 sets of alga Photosynthesis	3 sets of alga Photosynthesis
Biology	1 tourism guide map	1 set of postcards	4 tourism guide maps
Other	Website	Data set 2 official presentations	1. 2 student paper awards. 2. Practical tourism guiding 3. 1 Promoting event and presentation

3.3 Teachers overcame challenges

There was quite a lot of pressure and uncertainty challenging our HSP program, especially during the first academic year. The HSP is a policy carried out by the NSC/MOST so that all participated schools were facing the accountability requirements. The high expectations and uncertainty of the outcome put pressure on our HSP program. The accountability pressure and uncertainty of the outcomes sometimes may limit the innovation of the curriculum. Fortunately, administrators, professors, and the teachers discussed to support teachers' teaching and tolerance uncertainty in HSP meetings.

The HSP policy offers the opportunity of deregulation so that schools can design their curriculum beyond official curriculum regulations. Therefore, HSP programs were able to have more flexibility in in-class time, curriculum design, assessments, and teaching methods. In our HSP program, the school principal and administrators were supportive to allow teachers to design their curriculum beyond restricted regulations. Moreover, this HSP program had more flexible class time. They could arrange students to do experiments or attend HSP activities during lunch breaks, after school, and sometimes on weekends. HSP program also had funding to invite experts to give lectures, to do more experiments, or to go to field trips beyond regular school settings. This HSP program also supported teachers to set their own learning goals for the students rather than following restricted goals set by the school or Ministry of Education. Therefore, teachers could adjust their students' learning goals from merely test outcomes to real science capacity and motivations.

The evaluation design used participatory evaluation approaches to encourage teachers to involve in program evaluation. From meeting records, teachers determined to focus on students' motivation and improving science capacity rather than merely test scores and experiments' outcomes. According to interviews and meeting records, using alternative evaluation approaches helped to reduce stress and encourage teachers' participation in the evaluation process. Teachers can also conduct professional development.

Teacher 1: In HSP, I can also improve myself to learn new knowledge.

The monthly meetings and discussions after class observations helped teachers, professors, and administrators to communicate with each other.

Discussions

Following the evaluation outcomes, there are three main lessons can be learned and responding to research questions. The HSP policy can serve as an example for improving science and technology education. This HSP program shows school-college collaboration may benefit both institutions. The government may promote science and technology education by supporting funding and offering flexible regulations. Last but not least, this HSP program evaluation indicated alternative evaluation approaches could become a more inclusive program evaluation.

1. **The school-college collaboration may support STEM education**

   In this HSP program, it showed that school-college collaboration could support developing STEM education. College professors, teachers, and students were all benefited from school-college collaboration similar to what AAHE (1993) stated. Moreover, this HSP program showed positive school-college collaboration could benefit STEM education. First, the school could get resources from the college. Professors and teachers could work together to design innovative and cutting-edge science technology curriculum. Second, high students could visit the college. They could understand how college STEM laboratories operated, and they could be motivated to choose STEM majors in the future. Third, professors could understand how high school taught STEM education and could offer feedback to improve STEM education. Moreover, school teachers could even conduct professional development by interacting with professors or colleagues.

The science learning experience in this HSP program was valuable for students. They might be more motivated in a STEM career. This HSP program evaluation showed school-college collaboration could benefit STEM education. Professors, teachers, and high school students all got the chance to interact and cooperate in STEM learning. This HSP program might serve as a positive example of school-college collaboration supporting STEM education.

2. Funding and deregulation can support STEM education

Our program evaluation showed a supportive science and technology education policy might result in positive outcomes. Science education policy is important so that students have the chance to learn science influencing their future careers (Falk et al., 2015). This HSP program showed a way to develop a successful innovative STEM curriculum. This outcome is similar to what OECD (2016b) stated about classroom autonomy. It showed that government funding could provide resources to develop an innovative curriculum. The funding could support teachers to design curriculum and arrange activities that differed from regular classes, such as professional lectures, field trips, and more costly experiments. The funding can also support schools to design various STEM programs different from traditional curriculums to encourage STEM learning. Teachers could educate students on truly capacity and motivation through diverse STEM curriculum designs.

The HSP policy offers deregulation opportunities for the teachers having more room for developing an innovative curriculum. Schools having more autonomy with flexibility could respond to local students' needs might have higher science scores. Policymakers may offer resources and flexibility beyond regulations to support the innovative STEM curriculums in the future.

3. Alternative evaluation approaches become inclusive and supportive

Alternative evaluation approaches, such as a participatory idea, may encourage stakeholders, especially the teachers to participate in the evaluation. Most policymakers and administrators tend to use objective-oriented evaluation emphasizing standardized outcomes. However, sometimes when evaluating innovative activities or education programs, there are other valuable considerations. STEM education may use diverse ways of evaluation (Lawrenz, Huffman, & Thomas, 2006). This HSP program turned out to make our program evaluation meaningful to stakeholders, especially to the teachers by encouraging their participatory. They were more willing to participate and be empowered in this HSP program evaluation. They could also conduct professional development by interacting with professors.

Conclusion

This evaluation study showed that the HSP policy provided funding to support school-college collaboration and deregulation might facilitate innovative STEM education and teaching. Through the school-college collaboration, professors, teachers, and students were able to work together. Students could learn more and increase their motivations in the STEM class. The funding and deregulations could support the innovative curriculum and teaching activities. Moreover, this HSP program used alternative evaluation approaches that encouraged teachers' involvement and empowered them. For program administrators or policymakers, these evaluation outcomes can offer insights for future STEM education programs and making policies.

Limitations of this study included a small-scale case study and a limited period of time. The models and sizes of school-college collaborations can be further explored. The direct cause-effect influences were hard to confirm because this HSP program study reminded only three years. It will be interesting to track how students perform in the future STEM career and how this program long-term influences. This kind of program may even extend to invite some low social-economic status background students to enroll. These programs may offer students the opportunity to discover their potential and interests in either a STEM career or attending higher education. It will also be interesting to look into the outcomes of the new round of Taiwan HSP policy or other similar policies in other countries.

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