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Research Article

An empirical study on integrating technology into statistics classroom practice

Ken W. Li

Hong Kong Institute of Vocational Education, China (ORCID: 0000-0002-4855-6257)

There has been much attention given to the use of technology in education; mostly concentrating on physical artifacts of technology to facilitate teaching delivery but little mentioning technology as a cultural resource to organize the learning environment promoting social interaction among students and between teacher and students. This paper thus attempts to derive a model of pedagogy in an IT environment taking social interaction in classroom learning into account and reports a process of validating the model through two observation studies and two questionnaire-based surveys. The first observation study took place in a lecture theatre where a teacher led a class discussion toward developing statistical concepts and showed that all students were attentive and participative. In the second observation study, the students in a computing laboratory were divided into small groups to solve statistical problems collaboratively. The first survey was conducted during the term time to interview students through which they reported their personal perceptions of and attitudes toward the educational use of technology. A questionnaire in the second survey was sent to the students via e-mail after the term time. In the questionnaire, they were asked to compare the experience of working in an IT environment between the classrooms using and not using a model of pedagogy in an IT environment. The students in the surveys reported that teacher facilitation of group learning in the statistics module with technology were different from other statistics modules they took in the same academic year because they appreciated group discussion that promoted social interaction and fostered working relationships, thus leading to construction of knowledge. These four studies show consistent results and evidence in supporting a successful implementation of the model into a statistics classroom practice. More importantly, the observation studies give a detailed account of peer collaboration, mutual assistance, and productive interaction in a process of discussion and the teacher sensitivity to adjust the means of scaffolding assistance that substantiate the survey findings.

Keywords: Higher diploma; Social organization of classroom; Statistical modelling

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1. Introduction

Many scholars have made different contributions to the enhancement of teaching and learning using technology in education, for instance, Roy et al. (2017) attempted to utilize multimedia technology to deepen student understanding of mathematical proofs. Soldano et al. (2019) designed an interactive environment to engage students in geometry learning using game technology. Liu (2019) discussed the capabilities of an online learning management system using Google cloud technology as individualizing learning to suit each student's learning needs or pace.

Address of Corresponding Author

Ken W Li, PhD, Hong Kong Institute of Vocational Education, Tsing Yi Campus, 20 Tsing Yi Rd, Sai Shan, Hong Kong, China.

✉ dr_ken_li@yahoo.com.hk

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Interestingly, Schindler and Lilienthal (2019) studied how visualization tools would provide a stimulus to the learning of geometry using eye-tracking technology. Tan et al. (2020) built an automated grading system for examinations and tests that aimed to provide student timely feedback and efficient course management. Among these studies, technology offers capabilities of educational delivery of teaching and learning materials, management of learning, and academic assessment but also supports dialogic teaching and learning (Wegerif & Mansour, 2009). Given technology as a cultural tool for shaping classroom interactions (Drijvers et al., 2010; Manouchehri, 2004), it has much to do with re-organizing an environment in which students and teachers or students among themselves develop learning partnerships to socially construct knowledge through peer collaboration, classroom discourse, as well as social interaction (Mercer et al., 2007; Nussbaum et al., 2009). This view of learning is a social process of learning that follows Vygotsky's sociocultural theory (1978). Vygotsky saw learning as a social process in which language is a tool for communication and thinking through which students interact among themselves or with their teachers. Students construct knowledge, solve learning problems or accomplish tasks with the assistance of verbal speech in the form of self-talk, student-student talk or student-teacher talk. Self-talk enables students themselves to articulate their mental processes and evaluate their thinking. Talking with others allows students to develop understanding of the context by keeping informed and responding to others' queries. Thinking and communication are linked when students exchange personal views, share information, insights and ideas, as well as offer assistance to their peers or seek help from their peers or teachers.

In this paper, the author presents a critical review of current research with a close examination of social processes of learning. Arising from his synthesis of this research, he proposed a model of pedagogy in an IT (Information Technology) environment aimed at quality teaching and learning to address the roles of IT, teacher guidance, and peer collaboration. An IT environment here is about students' interactions with physical surroundings and social atmosphere where learning takes place at the time teacher was demonstrating how to program Excel and how to interpret Excel output, and students were collaborating on learning tasks using Excel and were using educational software to achieve a better understanding of abstract concepts. The model takes a learner's perspective involving a set of parameters: students' participation, peer collaboration, social interactions among students, student-teacher interaction, and task engagement in the statistics module, Applied Statistical Methods (ASM). To validate the model, the classroom episodes of the module, which were videotaped or audiotaped were analyzed and reported. In addition, two questionnaire-based surveys about their perceptions and attitudes toward the educational use of technology were conducted. The survey data were analyzed, and the survey findings were also reported. All these reports were consolidated to generate a comprehensive report to address the research question of how the model of pedagogy in an IT environment was successfully implemented in a statistics classroom.

2. Literature Review

Teacher educators and researchers (e.g., Bozkurt & Ruthven, 2017; Drijvers et al., 2010; Geiger, 2014; Goos, 2014; Louis, 2012; Manouchehri, 2004; Ruthven, 2014; etc.) theorized that there are interactions among students, teachers, and technology when learning takes place. Students generally interact with technology when inputting data, commanding digital devices, reading electronic displays, and so on. Technology is regarded as a physical artifact concerning the partnership between technology and students when working on the same task. There are social interactions among students; they use verbal communication to share information or knowledge, ask questions, or give feedback and they may also use nonverbal communication like pointing at a certain part of an electronic display when interacting with technology. Evidently, technology is not confined to physical artifacts, but a tool, in a wider context, that probably provides cultural resources in a way that facilitates social interactions or stimulates discussions among students (Wegerif, 2015) or foster collaborative learning (Schwarz & Asterhan, 2010).

Goos (2004) and Manouchehri (2004) reported a detailed account of the community of inquiry within a technology-enriched classroom. In Goos's study, students played different roles in the inquiry process after the teacher had demonstrated mathematical concepts using an experimental approach. The students presented their own standpoints, compared or validated the perspectives and beliefs of their peers, thus stimulating their thinking about how to relate mathematical representations with mathematical operations. Through the process, they achieved a conceptual understanding from a more comprehensive view with teacher's feedback.

Manouchehri (2004) supplemented the context of a community of inquiry as including the roles of teacher which were about to determine the context of mathematical inquiry; select appropriate tasks for mathematical exploration, analysis, problem solving, exposition, and so on; and orchestrate discussions among the students. In a technology-enriched classroom, instrumental orchestrations are in support of social processes of learning. The orchestrations are about turning digital artifacts as well as tools into an instrument to achieve learning aims and objectives with an emphasis on students' acquisition of knowledge and development of thinking during which there are social interactions among students or students and teacher (Geiger, 2014). For instance, a teacher demonstrates how to use digital tools, (i.e., "Technical-demo" orchestration); explains output displays from electronic devices (i.e., "Explain-the-screen" orchestration); and illustrates the relation between the electronic displays and terminology, concepts, mathematical tools, etc. in hardcopy learning materials (i.e., "Link-screen-board" orchestration). A teacher or students may discuss mathematical ideas or issues arising from electronic displays (i.e., "Discuss-the-screen" orchestration), compare their perspectives and justifications, validate conjectures or reconcile their divergent or conflicting opinions (i.e., "Spot-and-show" orchestration), and present their work or illustrative exposition for their specific arguments (i.e., "Sherpa-at-work" orchestration). The students actively participated in discussions among themselves, discussions held around technology provided representational tools for thinking and a mediating tool for communicating their thoughts. They eventually achieved a better understanding and successfully searched for deeper or implicit meaning of mathematical knowledge.

Geiger (2014) discussed the roles of technology in relation to student learning within the following two different situations. In small-group learning, technology facilitates student collaboration and engagement in a group interaction; digital artifacts such as computer output provided a stimulus for discussions among students. The discussions arise from students' different interpretations and understandings of the output. In whole-class settings, technology contributes to the establishment of a community of inquiry in which students are expected to share information, knowledge, insights, or ideas; give comments and suggestions as well as grounds for justification or defense; or raise questions to challenge or criticize through verbal exchanges. The way they exchange knowledge aims to pool the intellectual resources so as to correct misunderstanding; make improvement; or reach a consensus. The above three studies depict the role of technology in stimulating conditions for social interactions and further in supporting productive interactions, but needing to satisfy preconditions, a teacher's abilities and positive personal orientations, good technological infrastructure, and adequate school resources. These preconditions were contextualized within the framework of Zone theories in the report of Goos (2009): Vygotsky's (1978) zone of proximal development (ZPD), Valsiner's (1997) zone of free movement (ZFM), and the zone of promoted action (ZPA). The ZPD is more about a teacher's professional learning with respect to mathematical knowledge, pedagogical beliefs, as well as content knowledge. The elements of ZFM include students' abilities, motivation, and behavior in addition to curriculum, teaching materials, assessment as well as school culture, resources, and support. Pre-service teacher education, teacher professional development, and interaction with teaching colleagues are the core elements of ZPA. There is also an interaction effect among these three zones on a teacher's willingness to integrate technology into classroom teaching, so they cannot be treated independently. Evidently, the knowledge and experiences teachers brought to school from their pre-service teacher education or professional development (the ZPA) influence their own abilities as well as beliefs (the ZPD) which in turn have an impact on students' motivation to learn (the ZFM). Social relationships among teachers within a school (the ZPA) would affect how they align or adjust their teaching practices to achieve a common goal or standard. Their students would attain greater conscious control over their learning (ZFM) if they can see the common goal or standard of the school. Teachers would hold positive beliefs about the usefulness of technology (ZPD) when finding their job performance better; provided that adequate school resources and supports are available (ZFM).

Goos (2014) further argued that these three zones would influence the development of a teacher's pedagogical identity in relation to confidence and beliefs about managing class time and resources as well as adapting and responding to the changes in curriculum and assessment requirements when integrating technology in classroom teaching and learning. Similarly, Bozkurt and Ruthven (2017) as well as Ruthven (2014) posed a model of pedagogy for successfully integrating technology into a classroom with an emphasis on teacher's roles and knowledge. The teacher should be mindful of the working environment, resource system, activity structure, classroom settings, teaching plan, curriculum script, and time management. Teachers should have technological and pedagogical content knowledge that is a blend of technological knowledge, pedagogical knowledge, and content knowledge with an understanding of the relationships and the synergy of these three types of knowledge. Besides knowledge, Clark-Wilson and Hoyles (2019, p.347) also considered a teacher's personal orientations in terms of affective variables, i.e., "goal, attitudes, dispositions, beliefs, values, tastes, and preferences" in their "Technological Pedagogical Content Knowledge" model. All these three models cover most parts of the ZPD, and a few parts of the ZFM and ZPA, and posit the factors affecting integration of technology as echoed in the study of Ince-Muslu and Erduran (2021).

Summing up, successful establishment of the community of mathematical inquiry was a result of an active process of negotiation with students' input and output while both teacher and students were exploiting technology within classroom contexts. Specifically, technology demonstrated here an educational role in organizing the learning environment to promote interaction among students as well as between students and a teacher was congruent with Vygotsky's sociocultural theory (1978). Of course, a successful integration of technology in classroom teaching and learning would also be dependent upon a teacher's personal orientations and technological pedagogical content knowledge as well as school resources and support.

3. Research Framework

Arising from a synthesis of literature review, the following sections propose a model of pedagogy in an IT (Information Technology) environment for a statistics classroom with an emphasis on developing thinking and reasoning. Prior to implementing the model, its feasibility needs justifying by using Goos's framework (2014). Following the implementation of the model in classroom teaching practices, this study draws from both qualitative and quantitative methods to collect data and then data analysis using a framework adapted from Drijvers et al. (2010) as well as Tharp and Gallimore (1988) to investigate the particular settings that could arise in organizing social interaction around collaborative tasks. Tharp and Gallimore developed a framework for categorizing ways in which teachers assist their students to learn, via instructions, feedback, contingency management, questioning, modelling, and cognitive structuring. Some teachers ask students to follow instructions without demanding higher-order thinking. Feedback is usually given to students' responses for correcting incorrect answers or assuring correct answers. Positive contingency management is to provide students positive reinforcement that would enhance their learning motivation or bolster their confidence prior to attempting more difficult learning tasks. A teacher may utilize questioning techniques to check student understanding; to initiate a discussion; to give directions in search for an answer; or to probe unsubstantiated assertions. Modelling is about to organize students' thought process toward an anticipated result through the thinking pathways a teacher created. Cognitive structuring is about helping students to synthesize new knowledge from consolidating and processing the information students have already acquired. Among these six means of teacher assisting student performance, the first three are more or less to maintain social interaction between teacher and students, whereas the remaining three are more to assist students to achieve specific learning objectives through students' thinking and reasoning.

Apart from using Tharp and Gallimore's (1988) classical framework, analysis of data was further conducted with the aid of Drijvers et al. (2010) to check how to enhance student understanding through the instrumental orchestration, namely "Technical-demo", "Explain-the-screen", "Link-screen-board", "Discuss-the-screen", "Spot-and-show", and "Sherpa-at-work" orchestrations. Sections 5 - 8 will elucidate how this model can facilitate statistics learning together with empirical justifications. Two questionnaire-based surveys and two observation studies were carried out to delve into social processes of teaching and learning of statistics within an IT environment. These two different approaches were adopted because each of these approaches aims at different purposes and has its own strengths and weaknesses.

Both surveys were conducted to solicit feedback from students. During the term, a survey was devised to interview students where they reported their personal perceptions of and attitudes toward the educational use of technology under these three circumstances: i) when learning alone, ii) when learning with a learning partner, and iii) learning with their teacher. A questionnaire-based survey is generally an efficient method to understand a large number of students' opinions, and lends itself to statistical analysis of data. The survey findings provide general answers but cannot lead to in-depth understanding of social processes in teaching and learning which demand explanations, and further enquiry. It is therefore necessarily supplemented by two observation studies. The first observation study was conducted in a lecture theatre equipped with digital facilities to capture interactions between the students and the teacher who led a class discussion toward statistical concepts. After lecture, students were offered with hands-on practice in a computing laboratory; they were divided into small groups to work at computers in the laboratory. Observations were made to capture social processes of teaching and learning in the laboratory in the second study. The teaching-and-learning episodes which were videotaped or audiotaped were analyzed and reported. After the term time, another survey asked the students to compare their learning progress, their learning process, the quality and quantity of interaction with their learning partners, the experience of working with their teacher, and the experience of working in an IT environment between the classrooms using and not using a model of pedagogy in an IT environment. The survey data were analyzed, and the survey findings were also reported. The research findings from the two surveys and the two observation studies were consolidated to summarize how social interaction was cultivated in an IT environment; and how such interactions among learning partners could promote thinking.

4. A Model of Pedagogy in an IT Environment

The model of pedagogy in an IT environment taking a learner's perspective involving a set of parameters, teacher, students, and the inclusion of IT was adopted by the teacher who taught a statistics module, ASM. The students (aged 19-22) were enrolled in the second year of a three-year full-time higher diploma program in Applied Statistics and Computing (ASC) in the Department of Information Technology in a post-secondary college. The college is a provider of vocational education and training with government funding, with about 6000 full-time students and 1500 part-time students in four academic departments: Business, Construction, Engineering, and Information Technology and aims at equipping students with practical or trade skills along with contemporary technology ready for employment. The ASC program was to equip students with statistical knowledge and practical skills to solve statistical problems with the aid of computer software (for details, refer to Table 1). Upon completion of the program, they were qualified to join the statistics workforce.

Table1
Applied Statistics and Computing Program Structure

Year 1	*Year 2*	*Year 3*
Applied Calculus	Applied Statistical Methods	Multivariate Analysis
Matrix Algebra for Statistics	Economic and Social Statistics	Time Series and Forecasting
Probability and Statistics	Introduction to Statistical Theory	Database with Applications Development
Microcomputer Applications for Statistics	Market Research and Survey Sampling	Data Mining Data Warehouses
Fundamentals of Computer Programming	Statistical Computing	Professional and Social Issues in Statistics and Computing
Business and Management Studies	Operations Research	Contemporary Technologies in Computing
English and Communication	Project Work	Final Year Project
Putonghua (Mandarin)	English and Communication for Statistics	Advanced English and Communication for Statistics

The model conceptualizes some ways in which socially organized practices contribute to statistics learning through increasing students' opportunities for peer learning and social interaction. The students were divided into groups of two; they were expected to work together in class and collaborate on a group project after class (see Appendix 1). Each group of students naturally sat together when attending a class held in a lecture theatre; they collaborated on the worksheets in a practice session conducted in a computing laboratory each week during the academic year. Instead of delivering lectures, the teacher led class discussions toward developing an understanding of statistical topics with practical application using the Excel and SAS (Statistical Analysis System) tools through "Technical-demo" orchestration, "Explain-the-screen" orchestration, and "Link-screen-board" orchestration. The students worked in pairs at computers to attempt collaborative tasks in a computing laboratory, and used "Discuss-the-screen" orchestration, "Spot-and-show" orchestration, as well as "Sherpa-at-work" orchestration.

Beyond the instrumental orchestrations, the teacher took great care to follow appropriate pedagogical practice in using computer software (see, Li, 2016). Prior to implementing the model of pedagogy in an IT environment in the context of a statistics classroom, it would be better to check the model feasibility with justifications in accordance with Goos's framework (2014) in terms of the ZPD, ZPA, and ZFM relating to the teacher's teaching qualifications and experience, students' academic background as well as the college culture.

4.1. Zone of Proximal Development (ZPD)

The teacher in the present study (the author of this paper) who is a Statistics lecturer in the Department of Information Technology shoulders administrative workload in addition to teaching duties. The zone of proximal development is about the teacher's background prior to starting his academic career. He has completed undergraduate and postgraduate degrees in Statistics as well as postgraduate diploma in education. He is a professional statistician and has extensive experience in the statistics industry. He holds the view that the synergy of taking both a statistician's practical and a teacher's pedagogical perspectives would equip students with statistical knowledge and techniques appropriate for their prospective careers in statistics. The view is quite similar to Clark-Wilson and Hoyles's (2019) suggestion of mathematical knowledge for teaching evolving from pedagogical knowledge and mathematical content knowledge.

The humanistic quality of the teacher is apparent in addition to his educational qualifications and professional background. The teacher has confidence, a positive attitude, as well as interpersonal and relationship skills. His manner with people is warm, pleasant, and caring, he can build rapport with people. He is willing to accept responsibilities and constructive comments. He holds a belief that humans are sensitive to new environments and quickly respond by adapting.

All of these are evident from the survey responses given by his students, annual staff appraisal reports compiled by the Head of the Department and Principal of the college, as well as the teaching proficiency reports written by his supervising teachers in the postgraduate diploma in education program.

A successful integration of technology into classroom teaching practice depends on a teacher's ability, such as technological knowledge (Bozkurt & Ruthven, 2017; Clark-Wilson & Hoyles, 2019; Louis, 2012; Ruthven, 2014). In the present study, the teacher's personal abilities, statistical knowledge, and pedagogical beliefs as well as content knowledge lie within the ZPD. The ZPD is of paramount importance because student learning is sensitive to the knowledgeable teacher (Sadler et al., 2013) who expresses confidence in his teaching efficacy and prepares lessons to ensure successful learning.

4.2. Zone of Free Movement (ZFM)

After the ASC students had successfully completed their Year 1 study, they became more mature, more confident, and more motivated. They were attentive in both lecture and laboratory sessions and submitted their assignments and projects on time. They demonstrated both positive learning attitudes and sound relationships with their classmates. They attained the elementary level of probabilistic and statistical concepts and were able to: present data correctly using statistical graphs and tables; perform simple statistical analysis using summary statistics and hypothesis testing; quantify uncertainty of an event; use probabilistic reasoning in justifying statistical findings and statements; and present statistical results and findings.

The teacher adjusted the curriculum in regard to the pedagogy in the realm of teaching and learning with technology. He developed educational software, IT-based learning materials, and teaching repertoires associated with the use of Excel and SAS for facilitating student learning. He designed practical tasks demanding problem analysis and formulation, statistical thinking, and statistical interpretation as well as reporting with the need for deploying technology to alleviate much of the computational and graphing drudgery.

The college in the present study has a culture of equipping students with practical or trade skills along with contemporary technology ready for employment; and maintaining staff skills appropriate for teaching, so it takes the initiatives in upgrading laboratory and workshop equipment as well as improving IT infrastructure for ubiquitous learning and efficient program management, such as program and module registration system, class attendance recording system, class timetabling system, marks recording system, and so forth.

The college emphasizes the importance of quality teaching and learning and conducts surveys to solicit students' feedback about the quality of teaching delivery in each module by each teacher, the learning environment and facilities of classrooms, as well as the adequacy of library resources. The survey results are strictly confidential but are reported to the relevant teachers and the college administrators involving the principal, the head of the respective academic department and the leader of the respective academic program for taking responsive actions for the enhancement of teaching and learning. One of the actions taken by the college is to urge the use of technology in teaching and learning with the provision of resources, supports, in-house training, and funding for staff development.

Lecture theatres and computing laboratories are common types of classrooms used for teaching and learning in this study and were equipped with computers connected to the internet and the college intranet, computer monitors, computer software, a data projector, a projection screen, microphones, and loudspeakers. In the event of equipment malfunction, a phone call could be made asking a designated technical staff member to address the problem immediately. There were ample desktop computers and monitors in the laboratory for a class of about twenty students, so a few spare computers and monitors would be able to deal with possible contingencies. A computer technician, who was stationed in an office next to the laboratory, could be called for technical support when necessary. The teacher utilized hardware, software, and human resources as fully as possible.

The implications of ZFM for teaching with technology are the determinants within school contexts regarding whether the integration of technology into classroom teaching and learning is successful. However, a student's abilities, motivation, and behavior, the adjustment of curriculum and assessment, the college culture and initiatives, as well as IT resources and technical support are justified within the ZFM.

4.3. Zone of Promoted Action (ZPA)

The teacher had prior experiences with using technology, including modelling statistical data by computer programming, and managing medical records using computer database systems. He regularly attended conferences on and engaged in training using technology in teaching and learning. He had keen interest, confidence, and competency in integrating technology into classroom teaching and learning. He took a proactive role in giving personal insights; he joined the e-learning steering group of the college; and he shared his experience of teaching and learning with IT with his colleagues in the meetings and symposiums organized by the college. He authored an instruction manual for those who were unfamiliar with the Moodle learning management system, but wanted to use it. In addition to gaining knowledge, the teacher's professional development included ways to interact with his colleagues in collaborative settings, thus creating the synergy needed to provide appropriate opportunities for achieving the integration of technology in classrooms. The success of the integration would also come from being in tune with his colleagues. Teachers in collaborative settings would thus develop better skills of integrating technology into classroom teaching and learning through their collective analysis and evaluation.

With the above ZPD, ZFM, and ZPA justifications, the model is viable. The following section applies the model to the specific context of teaching and learning of regression modelling in order to elaborate and illustrate the potential roles of technology, peer collaboration, and teacher guidance.

5. Questionnaire-based survey during the term time

The statistics module, ASM was taught by the teacher in two types of classrooms, i.e., a lecture theatre and a computing laboratory. The entire class of fifty-eight students attended a common lesson in the lecture theatre with about seventy seaters. After lecture, all the students were offered with hands-on practice in a computing laboratory that could only accommodate about twenty students. Hence, students were divided into three groups; three identical practice sessions were scheduled in three different time slots. Students within each of the groups formed pairs to work at computers in the laboratory in one of the practice sessions in order to promote an exchange of views, sharing of knowledge, and resolution of problems in order to cultivate a higher level of involvement and collaboration.

At the beginning of a practice session, the teacher reviewed important concepts and highlighted the source, context, and contents of data as well as relevant statistical tools on the laboratory exercise he assigned to the students. Each of the exercises was designed to apply specific concepts and make use of statistical tools and Excel to solve regression problems. Each pair of students shared the same computer workstation and regulated their own learning. The teacher acted as a facilitator of fostering students' learning and regularly monitored the learning progress within each pair. He occasionally intervened to redirect their discussions toward hypothesizing, interpretation, and reasoning rather than limiting to information seeking or exchanges.

5.1. Research Participants and Method of Data Collection

The fifty-eight HDSAC students voluntarily participated in the first questionnaire-based survey. After they had attended both lecture and practice sessions for about six weeks, they should be familiar with physical and social environments of the statistics classroom. Then, the survey that involved interviewing each of the students was conducted to give his/her personal perceptions of and attitudes toward the educational use of technology under these three circumstances: i) when learning alone; ii) when learning with peers; and iii) when learning with the teacher. All fifty-eight HDASC students attempted all questions in the questionnaire, i.e., the response rate is 100%.

5.2. Data Analysis

The findings of this survey were extensively reported by the author of this paper and his colleague in their book chapter, Li and Goos (2020); the following subsections, 5.2.1-5.2.3 presented an extract from the findings with further interpretations adhering to the present context, an integration of technology into classroom with a focus on three important issues: technology as a physical artifact when learning statistics individually (Subsection 5.2.1) and technology as a cultural tool when learning with their peers or teacher (Subections 5.2.2 and 5.2.3). Students' responses given to the survey are reported under these three subsections. In each subsection, the survey questions with a common theme were grouped, together with a summary of the corresponding responses.

5.2.1. Technology as a physical artifact when student learning alone

The six questions in this subsection were intended to evaluate how a digital tool, IT would facilitate student learning.

- Does IT widen or narrow down your scope of learning?
- In what ways, does IT widen your scope of learning?
- In what ways, does IT narrow down your scope of learning?

Among 58 students, 89.7% believed that IT widened their scope of learning, whereas 8.6% and 1.7% had neutral and negative responses respectively. The students who gave positive responses reported that IT widened their scope of learning by appreciating applicability of statistics in the real world and by developing thinking and reasoning skills through data experimentation using statistical software. On the other hand, few students complained that the IT infrastructure limited exploration of statistics due to slow information traffic. The positive responses illustrated the significance of software tools, whereas negative responses displayed hardware problems.

- Do you have better learning progress learning with or without IT?
- In what way, do you find you have better learning progress when learning with IT alone?
- In what way, do you find you have less learning progress when learning with IT alone?

About 79.3% of 58 students had better learning progress when learning with IT because they exploited the use of IT as its important role for enhancing student understanding through hands-on animation and visualization tools, data experimentation using statistical software, and social media for seeking learning assistance outside classrooms. However, 20.7% gave a neutral response among which there were also some negative comments about student-centered orchestrations when encountering hardware problems, unmanageable software tools, or difficult computer syntax but none (0%) gave a negative response.

5.2.2 Technology as a cultural tool when student learning with their peers

The following two questions aimed to collect students' perceptions of peer learning within an IT environment.

- When learning with IT, do you have better learning progress when working alone or working with your learning partners?
- For what reasons do you find you have better or worse learning progress when working with your learning partners in an IT environment?

The majority of students, 89.7% of 58 students had better learning progress when working with their learning partners because they exchanged views for co-constructing knowledge and rectifying misconceptions or they were offered learning assistance by a more competent peer. All these are examples of intellectual exchanges through which they found better progress. Five students, 8.6% gave a neutral response; only one student (1.7%) had worse learning progress because of being unable to resolve disagreement to reach consensus

The main objective of the following five questions was to achieve a deeper understanding of peer learning within an IT environment.

- How much knowledge do you want to share with your learning partners when learning with IT?
- How much knowledge do your learning partners share knowledge with you when learning with IT?
- What type of knowledge do you want to share with your learning partners when learning with IT?
- What type of knowledge do your learning partners want to share with you when learning with IT?
- How do you share the workload with your learning partners?

A large majority of students, 89.7% shared much knowledge with their learning partners, whereas 82.7% of their learning partners reciprocated much knowledge. They shared conceptual, procedural, technical, tactical or analytic knowledge as well as knowledge around statistical communication skills with each other. Only one student (1.7%) shared little knowledge, whereas 3.5% of their learning partners reciprocated little knowledge. Five students (8.6%) gave a neutral response, whereas 13.8% of their learning partners gave a neutral response.

In addition, students reported that learning tasks that were equally shared with their partners were mostly cognitively oriented, such as problem formulation, approaches to problem solving, graphing and computing tasks, and statistical reporting, with a display of these relations in a reciprocal way. Evidently, they gave support by offering involvement in their learning initiatives. They had been collaborating closely with their learning partners to ensure successful learning.

To summarize the above responses, the interaction with their learning partners is likely to be reciprocal and symmetric. Students took the initiative to share knowledge and communications skills. They were happy to see their learning partners assist performance; students felt fairly treated and benefitted from group bonding. Their self-reporting of positive reciprocal relationship with learning partners indicated that they appreciated each individual's contribution in striving toward their common learning goal.

The next three questions studied the working relationship between students and learning partners.

- Compared with a non-IT environment, does an IT environment help you foster a better or a worse interpersonal relationship when working with your learning partners?
- Are you co-learning or competing with your learning partners when working in an IT environment?
- Are your learning partners co-learning or competing with you when working in an IT environment?

The largest proportion of students, 60.3% thought that an IT environment helped students foster better interpersonal relationships. It is worth nothing that 36.2% of students gave a neutral response and 3.5% had a negative response. About 90% of students reported that peer learning arose from a collaborative basis rather than from a competitive basis. Peer learning here features the development of learning strategies or achievement of common learning goals with concerted effort and displays a positive working relationship between the student and their partners. However, 10% of students gave a neutral response but none (0%) gave a negative response.

To examine the importance of communication between the students and their learning partners, the following questions asked.

- Is the communication between you and your learning partners beneficial or not beneficial to your learning process?
- In what circumstances, do you find the communication between you and your learning partners are beneficial to your learning process?
- In what circumstances, do you find the communication between you and your learning partners are unbeneficial to your learning process?
- How do you think you can improve the communication between you and your learning partners in order to achieve mutual benefit from learning?

Most students (91.4%) believed that communication with their learning partners were beneficial to their learning process, together with the following supplementary responses within social and cognitive contexts. Sharing of personal views, clarification of misconceptions and/or misunderstanding, resolution of divergent views are social in nature when compared with these responses given by the students like monitoring peer's learning progress; determining goals; formulating strategies; and stimulating one another to think. These responses are cognitive in nature, but it is noteworthy that addressing social issues is a prerequisite for peer learning. Four (6.9%) students gave a neutral response, whereas the remaining student (1.7%) had a negative opinion. Among these responses, few students reported communication that was not beneficial when less competent learning partners could not assist their learning.

More than half (56.9%) of 58 students said that there was no need to improve communication with their learning partners because they were satisfied with the communication. About 43.1% of students wanted to improve communications with their learning partners by taking the initiative in chatting with them; listening attentively to peers; being be more empathetic about their situation and feelings; and providing moral support where necessary. All of these approaches to improving communication are in the social context.

5.2.3 Technology as a cultural tool when student learning with their teacher

The following two questions aimed to gather students' general views about the teacher's intervention.

- Do you find the teacher's intervention beneficial or unbeneficial to your learning process?
- In what circumstances, do you find the teacher's intervention beneficial or not beneficial to your learning process?

Almost all students, 93.1% thought the teacher's intervention was beneficial. Intervention is a social process within which the teacher offered students various means of scaffolding assistance, such as giving feedback and instruction, modelling thinking, questioning, and cognitive structuring. Apart from these typical means of scaffolding assistance, some students mentioned that the teacher maintained an active dialogue with them to encourage their participation and involvement, share their views as well as ideas, and respond to assistance they sought. Four students (6.9%) were neutral, but adding a negative comment; they felt uncomfortable when their mistakes were pointed out during the teacher's intervention. Nevertheless, none (0%) found the teacher's intervention not beneficial to their learning process.

This question, "How does your teacher orchestrate the learning activities in the computing laboratory?" enabled students to express the role and significance of the teacher in the learning process. Students reported that their teacher orchestrated the learning activities in computing laboratory within social and cognitive contexts. The teacher fostered an amusing climate for learning; organized meaningful learning activities; established a community of practice and inquiry; provided prompt feedback to students; and motivated students to excel at tasks. He utilized teaching and learning resources, such as providing handouts as well as computer hardware and software.

The next three questions sought to discover whether or not IT was regarded as a vehicle of education delivery that could replace human teaching.

- Would you like to learn with a teacher or IT?
- Would you like to learn with your learning partners or IT?
- Would you like to learn with learning partners or a teacher?

Among 58 students, 39.7% preferred learning with a teacher to IT, 1.7% preferred learning with IT to a teacher and 58.6% gave a neutral response. When being asked to choose between learning partners and IT, 51.7% preferred the former, while 41.4% had no preference and 6.9% few preferred the latter. Students were evenly divided in choosing to learn with a partner (24.1%) or the teacher (20.7%), and 55.2% gave a neutral response. To sum up, students would like to interact with humans rather than IT because either peers or their teacher understood their feelings, emotions, moods, and learning needs more in order to offer social support.

The prime purpose of the following two questions was to learn students' experience of interacting with their teacher.

- Do you have better or worse learning progress when working with your teacher in an IT environment?
- For what reasons do you find you have better or worse learning progress when working with your teacher in an IT environment?

Many students, 86.2% had better learning progress when working with their teacher in an IT environment because their teacher was attuned and responsive to their questions and also created and maintained a positive and warm classroom atmosphere conducive to learning. Eight students (13.8%) gave a neutral response, but none (0%) gave a negative response. Apart from the neutral respondents giving the positive reasons similar to the above, they also gave negative reasons. Their teacher did not give direct instruction; scaffolding assistance offered by the teacher slowed down their learning progress.

The above survey findings show that students appreciated technology as a physical artifact, for instance, by using tangible user interface, such as an icon, a scroll bar, a command button, a pointer, a mouse cursor, etc. and software features, such as data processing, computing, graphing, etc. to explore statistical ideas; do statistical experiments; solve statistical problems; critically evaluate statistical logic; etc., but a drawback of the artifacts was hardware problem. Technology as a cultural tool would influence social interaction among students and between teacher and students in the process of teaching and learning. Productive interaction between students came from intellectual exchanges, constructive discussion, positive interpersonal relationships, collaborative work, and goal attainment with concerted effort. The teacher utilized computer hardware and software; established a community of practice and inquiry; and provided feedback or scaffolding assistance to students to guide students' knowledge construction through social interaction. These are social aspects of learning within a Vygotskian context.

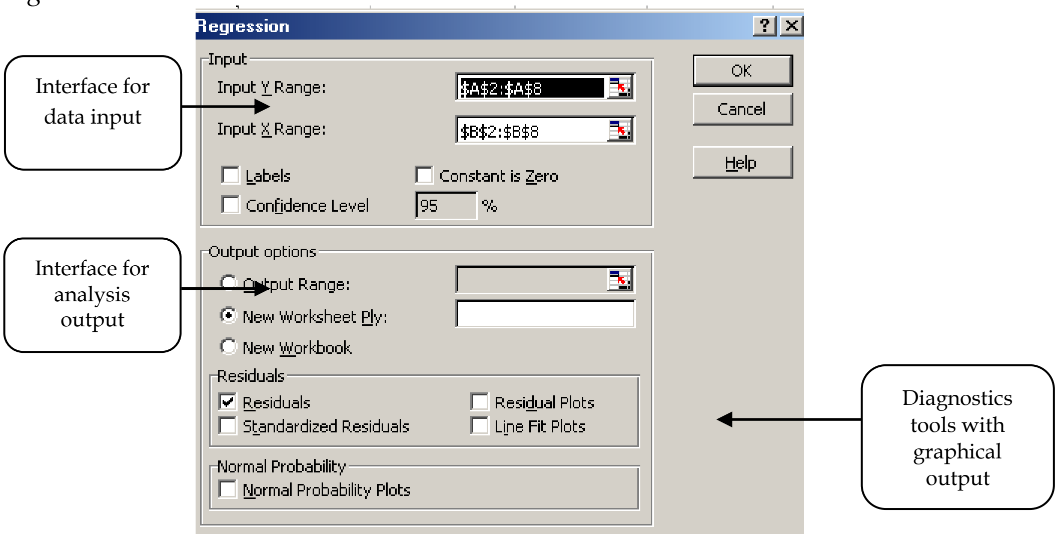
6. An Observation Study Conducted in a Lecture Theatre

The detailed practices of teaching and learning in which the teacher adopted the model of pedagogy in an IT environment aimed at developing students' statistical understanding and skills through a community of inquiry were videotaped during lessons. The video camera was set in front of the class to capture interactions between the teacher and the students which were analyzed and reported in this section; all student names are pseudonyms.

The teacher led a class discussion toward developing the outlying and influential concepts (a data point appearing to be remote from the range of x-values or off the track of a proposed regression line) after reviewing key concepts in the past few lessons. By using interactive educational software, he asked students to watch the changes of a line with respect to its slope and intercept when relocating a point with mouse drag-and-drop. He asked a series of straightforward questions in connection with each mouse drag-and-drop action. The answers attempted by his students steered them toward a deeper exploration of the concepts through the "Explain-the-screen" orchestration. The questions raised by the teacher were not only relevant for students to develop some intuitive understanding of concepts but also called their attention to more important outlying or influential issues.

The teacher managed the Windows feature to position PowerPoint slides and an Excel spreadsheet in two windows side-by-side. In the PowerPoint window, the definitions of relevant statistical terms were shown. Prior to programming Excel, the teacher reiterated the proper usage of the regression tools on the PowerPoint slides and selected the corresponding tool in the Excel window using the "Link-screen-board" orchestration because correct selection of a statistical tool is a prerequisite to prevent students from producing meaningless or incorrect results. Through the "Technical-demo" orchestration for command prompt, he highlighted the user interface for data input, analysis output, as well as the diagnostics tools with graphical output (see Figure 1). Excel is here used as a tool for alleviating much of the computational and graphing drudgery; facilitating a detection of outliers in data; and helping students to elicit spatial reasoning when reading graphical output for regression diagnostics (see Li, 2014).

Figure 1
Regression tools in Excel



On the Excel spreadsheet, the teacher elaborated the context, content, measurement, and measurement units of electricity consumption data through the "Link-screen-board" orchestration and then initiated his students to identify a dependent variable (y) using questioning. Wendy answered the questions voluntarily but the teacher found her questions correct but incomplete. After he had modelled students' thinking, she gave a complete and correct answer but without any justification. He wanted to know how her thinking was developed, so he asked Wendy to justify. While Wendy was striving to justify the answer, her learning partner, Kathy offered her assistance as a social support to alleviate Wendy's stress. Kathy was then more participative and answered the question correctly. Their good partnership is evident and in accord with survey results in Subsection 5.2.2, Technology as a cultural tool when learning with their peers.

The teacher continued the discussion by asking students to confirm the independent variable (x). Kathy had held discussions with her neighbours but she could only give simple answers to maintain interactions with the teacher. The teacher asked two types of questions; the first type was to help students develop reasoning and the second type was to offer his students a directive requiring recall of the meaning of an independent variable. Kathy answered the directive question correctly. After giving feedback to confirm her answer, the teacher recapped it to link to the data content to complete Kathy's explanation. While both students were answering questions, their classmates' gestures or facial expressions showed they watched and listened attentively.

There is an IRE (Initiate-Response-Evaluation) pattern in the verbal exchanges between the teacher and Wendy or Kathy, followed by directed questions. Questions were initially posed by the teacher to invite all students to join a discussion. After evaluating the answer quality, he raised directed questions to model student thinking toward more complete or better answers.

In the lesson that follows, the teacher moved on to addressing more important issues in outliers, e.g., whether or not an outlier distorted a model fitting; how the outlier distorted the model fitting, and how to solve outlying problems. After the teacher had run an Excel program to fit a regression model to the electricity data, a residual plot popped up on the projection screen. Through this "Explain-the-screen" orchestration, he offered visual cues by using a mouse pointer to call students' attention to the contrast of observed values with predicted values on the residual plot. Shortly after, the teacher initiated the following discussions by posing a question (see Table 2), Kathy answered correctly but did not follow the visual cues (Excerpt 2). She insisted on using a quantitative approach, R^2 to assessing a model fitting (Excerpt 4) but it, in fact, did not indicate which part(s) of the model fitting had problem(s) and how the problem(s) arose. The teacher therefore posed another question so as to strike a note of warning about the consequence of an existing outlier using a graphical approach through the "Explain-the-screen" orchestration (Excerpts 3 and 6) but she gave a simple answer, "*No!*" without providing any explanation.

Table 2
Classroom discussion about assessing a model fitting

Excerpt	*Teacher/Student*	*Verbal contents*
1.	Teacher:	Does this graph (residual plot) show the model fits the data well?
2.	Kathy:	I think the R^2-value will be quite low (small) because there is an outlier.
3.	Teacher:	Okay! It could be an outlier. Is there any problem resulting from the model fitting?
4.	Kathy:	Yes, because the R^2-value is quite low (small) so it indicates that the model does not fit the data well.
5.	Teacher:	Yes!
6.	Teacher:	Can we use it (the regression model) to make accurate prediction?
7.	Kathy:	No!
8.	Teacher:	Why not?

Kathy's neighbour, Chris had a puzzled look on his face, so the teacher asked him but he could not answer (Excerpts 9 and 10). The teacher extended the questioning context to model the consequence of an outlier (Excerpt 11), together with a visual cue to draw students' attention to the deviation between an outlier and the corresponding data point. The cue through the teacher's "Explain-the-screen" orchestration appealed to Chris about the outlier on the residual plot (Excerpt 12). Chris gave some correct answers but not in details about the consequence of the outlier. The teacher provided an implication of poor model fitting, followed by his question to reckon with the problem (Excerpt 13), a cued elicitation (Excerpt 15), and a remark about an outlier (Excerpt 17). Chris gave correct answers (Excerpts 14, 16, and 18). The teacher asked Doris to make a deduction about what a poor regression model fitting implied (Excerpt 19). She gave a correct answer, but incomplete (Excerpt 20); the teacher eventually consolidated and reorganized the students' inputs to give a complete answer (Excerpt 21).

Now it was about time to classify whether an outlier was respect to x or y, or both x and y. This classification is crucial as it affects how to resolve an outlying problem. The teacher asked questions about a statistical term describing the outlying phenomenon (Excerpt 22) but Doris could not give a concise answer (Excerpt 23). She sought assistance from her neighbours, Chris and Simon. Simon discussed with Doris when pointing at a statistical term on her note, and she then gave a better answer (Excerpt 25). The teacher found her answer was not legitimate enough so that he revised the answer (Excerpt 26). Doris knocked her head to show her agreement.

Table 3
Classroom discussion about the consequence of an outlier

Excerpt	*Teacher/Student*	*Verbal contents*
9.	Teacher:	What's the problem?
10.	Chris:	…
11.	Teacher:	If you say the model cannot provide us an accurate prediction, what is the problem?
12.	Chris:	There is an outlier.
13.	Teacher:	Yes, but what's the problem underlying? The model does not fit the data well and the problem is related to the estimates of regression parameters, right? … So what is the problem?
14.	Chris:	The slope may change.
15.	Teacher:	The slope maybe influenced by an …
16.	Chris:	An outlier
17.	Teacher:	It could also affect the estimates of intercept, right?
18.	Chris:	Yes.
19.	Teacher:	Now, how does the problem arise?
20.	Doris:	The outlier …
21.	Teacher:	Yes, the outlier is suspected and … may not be consistent with the proposed regression line, okay?

Table 4
Classroom discussion about differentiating between outliers based on the x-axis orientation

Excerpt	*Teacher/Student*	*Verbal contents*
22.	Teacher:	Can you give a statistical term for the problem? … How do you call this statistical phenomenon?
23.	Doris:	… It's an outlier with respect to y.
24.	Teacher:	Because …
25.	Doris:	Because it is out of the range in y (-values)
26.	Teacher:	Should we say, the outlier is off track of the proposed regression line rather than out of range of *y-values*? Okay?

The teacher switched the discussion toward the task of checking for an outlier with respect to y or x, (Excerpt 27). Not only did the teacher provide a visual cue, Simon also used the "Discuss-the-screen" orchestration to assist Doris in drawing out the information they were seeking by using a pen pointing to the outlier displayed by the data projector. Simon became more vocal and answered the question correctly and completely, together with a valid reason by successfully defining the meaningful data range of the *x-variable* (Excerpt 28). The teacher exhorted Simon to continue to justify the outlier for being with respect to y but the justification given by Simon was not well grounded (Excerpts 29 and 30). Before progressing further, the teacher recapped the procedures of classifying whether an outlier is with respect to x or y (Excerpt 31).

Through using the "Technical-demo" orchestration, the teacher programmed Excel after removing the outlier and reformulated questions to prompt students to contrast the changes to the Least Squares Estimates of regression parameters using the "Link-screen-board" orchestration (Excerpt 32). Cindy attempted the question voluntarily through the "Spot-and-show"zorchestration; she compared the old and new Excel outputs, i.e., regression results and residual plots popped on the project screen (Excerpt 33). The teacher affirmed and recapped the

Table 5
Classroom discussion about differentiating between outliers based on the y-axis orientation

Excerpt	*Teacher/Student*	*Verbal contents*
27.	Teacher:	So how can you decide this outlier is with respect to y instead of x?
28.	Simon:	In the given model, the range of x is from 15 … around 15 and 30 and the outlier (suspected) is within this range.
29.	Teacher:	Yes!
30.	Simon:	In the given model, the range of y is within 0 and 30000 but the outlier, the y is more than … around 120000 so it is extremely out-of-range in the y-*axis*.
31.	Teacher:	I agree with the explanations of an outlier with respect to x because the observation is out of the range of *x-values*. But, again when we identify an outlier with respect to y, we are looking at the regression line … and compare whether it is off track of regression line, okay?

correct answer given by Cindy and elaborated that an outlier would cause unreliable estimates of regression parameters (Excerpt 34). Both students and teacher used instrumental orchestrations that provided tools for encoding and decoding graphical data.

Table 6
Classroom discussion about a negative impact of an outlier on regression estimates

Excerpt	*Teacher/Student*	*Verbal contents*
32.	Teacher:	How does this outlying observation affect the Least Squares Estimation? Now, I'm going to remove this point and give you another output; how does this outlier affect the Least Squares Estimation?
33.	Cindy:	It changes the slope of the regression line.
34.	Teacher:	Yes, it changes the slope of the regression model. That is, the Least Squares Estimates of regression parameters are substantially different from the true regression parameters.

After identifying the outlier problem, the next concern is to solve the problem; the teacher asked suggestions for tackling the problem (Excerpt 35). Liza gave a correct answer; the teacher recapped her answer and exhorted his students to propose more ways to resolve the problem. He then used directed questioning (Excerpt 37) as a hint; Liza discussed with her neighbours, Cindy and Susan. Susan took turns answering the question (Excerpt 38). The answer was correct but the teacher still expected more alternative answers (Excerpt 39). Susan did not answer the question but repeating the teacher's prompt to maintain social interaction with the teacher (Excerpt 40). He proposed another alternative by questioning and recapped to connect seemingly unconnected answers given by Liza and Susan to remind them an input error could arise from incorrect data measurement, incorrect data recording or incorrect data entry. He looked for one more way of tackling the problem by questioning (Excerpt 41). Liza answered correctly (Excerpt 42), and he elaborated on her answer (Excerpt 43). Questioning used by the teacher served to direct his students' development of statistical thinking as well as reasoning although Cindy listened to the discussion without participating. The verbal exchanges between the teacher and the students in question-and-answer form also modelled the heuristics for solving an outlier problem in the way that could be easily seen by the students.

Table 7
Classroom discussion about how to resolve an outlying problem

Excerpt	*Teacher/Student*	*Verbal contents*
35.	Teacher:	How can we tackle this problem?
36.	Liza:	Remove the outlier.
37.	Teacher:	We can remove the outlier. What else can we do? … Are you sure your data is (are) correct?
38.	Susan:	Check whether or not there is an input error.
39.	Teacher:	And what else?
40.	Susan:	And what else ...
41.	Teacher:	(How about) incorrect measurement? … We can check the outlier whether or not the outlier is caused by incorrect measurement, recording or entry of data, okay? … And what else can we do?
42.	Liza:	Data imputation
43.	Teacher:	We can make use of an advanced statistical technique, such as data imputation.

An outlier may turn out to be influential if affecting the reliability of the regression estimates irrespective of whether it is with respect to x or y or both x and y, so the justification of influential characteristics is crucial to resolution of an influential problem. The teacher presented two residual plots as visual cues; one with an outlier and another with the outlier removed and gave students instructions through the "Link-screen-board" orchestration to call for specific actions (Excerpts 44, 46, and 48), followed by questions. Most instructions were to shift students' focus to the original model contrasting with the revised model; only two simple instructions were to give command, "Look" and "Read". In between the instructions, Kirk, Faye, or Liza did not give good answers. Kirk missed the teacher's instructions and made his classmates laugh by not paying attention to the instructions. The sound of laughter revealed that they were silent but participated in the discussion and might make Kirk more aware. Kirk was embarrassed but shortly after he read the model aloud and correctly (Excerpt 45). The teacher asked them to justify their answers. When Faye was endeavoring to fix the influential problem, Liza gave her support as showing learning partnership.

The discussion in the lesson was a form of interaction where the teacher invited all the students to respond. Some students gave responsive or simple utterances and nonverbal responses, the content of subsequent utterances became richer after the teacher had provided a structure for students' thinking through the means of questioning and modelling in conjunction with the teacher-centered orchestration or student-centered orchestration. Among the three types of teacher-centered orchestration, the "Explain-the screen" orchestration was mostly used in order to offer visual cues as a way of modelling students' thinking and the acts of classifying the type of an outlier. Questions were asked for justification or instructions were given after the "Link-screen-board" and "Technical-demo" orchestrations in addition to the "Explain-the screen" orchestration. Questioning was extensively used by the teacher as elicitations of knowledge from students and a means of organizing students' thoughts toward task accomplishment; offering direction toward goals; calling for verbal responses to propose ways of solving a problem so to adjust teacher's scaffolding assistance or utterances. Instructions were given to requests for specific actions. In response to the teacher, the students made their ideas available through verbal responses. Their thinking was further developed by having teacher's recap, elicitation, repetition, reformulation or exhortation as the discourse features conducive to learning shown in Mercer (2000). More

Table 8
Classroom discussion about whether an outlier is influential

Excerpt	*Teacher/Student*	*Verbal contents*
44.	Teacher:	Now, let's say, I found a mistake in data entry and I had corrected the mistake. An updated residual plot of *y* versus *x* was obtained. … Compare these two residual plots. … Look at the regression model (with the outlier removed). … Kirk, read the regression model aloud.
45.	Kirk:	Y = electricity …. Y = 354.31X + 1206.8+ε
46.	Teacher:	Okay! This is the regression model for the data. I have corrected the mistake and re-fit the model. I obtain this (revised) model (with the outlier removed). …. Look at the original model. What is the regression model?
47.	Faye:	Y = 100.16 X+8364.5+ε
48.	Teacher:	Compare between the original and revised models (i.e., a removal of the outlier), what changes occur to the model fitting? Can you discuss whether the outlier is influential? … We have the original scatterplot and this is the (corresponding) regression model. This is the updated scatterplot and the regression model. … Now, compare these two scatterplots and regression models, can you discuss whether this outlier is influential?
49.	Liza:	Yes, it is influential.
50.	Teacher:	Why?
51.	Liza:	Because it affects the slope of the regression line … regression model.
52.	Teacher:	This is influential because the removal of such outlier reduces the deviation from the regression line and improves the overall fitting of a regression line, okay? This is the point you have to make it clear.

importantly, the teacher utilized technology as a cultural tool to stimulate conditions for interacting with the students (as shown in the survey results in Subsection 5.2.3) and promoting interactions among students. Productive interaction or learning partnership results from peer support, mutual assistance, knowledge sharing and intellectual exchanges (as shown in the survey results in Subsection 5.2.2). These interesting findings are congruent with the survey results.

7. An Observation Study Conducted in a Computing Laboratory

After lecture, students formed pairs to attempt regression tasks in the computing laboratory (for details, refer to the laboratory facilities in Subsection 4.2, Zone of Free Movement). Each pair of students shared the same computer workstation and took turns in keying data and programming Excel as they worked together on the set tasks. While they were accomplishing regression tasks collaboratively with their teacher or peers, there was necessarily a substantial amount of talk between them. The talk was audio-recorded and the conversations were transcribed in full, with relevant excerpts being selected for analysis by adopting the framework of Tharp and Gallimore (1988).

The following excerpts concern two students, Bill and Pansy working altogether at a computer to attempt the tasks set on the laboratory exercise through instrumental orchestrations. After reading the task requirements and the set of given data in the context of social security payment, they accessed and imported the data in a spreadsheet format from the college computer server to check the characteristics of the data. To program Excel through the "Discuss-the-screen" orchestration, they selected the regression tool, inputted the data, did regression diagnostics, and determined where to store the regression output (refer to Figure 1). To interpret the output using "Spot-and-show" orchestration, they attempted to validate the estimates of regression intercept and slope, but found the slope estimate did not make sense. They raised the issue during the teacher's intervention, but the teacher did not directly address it. He raised two questions; one was to make a request for justification. Another one was a directive question to structure their thinking toward tracing how the problem arose. Unfortunately, both students did not give any meaningful answer but just simple responses to maintain social interaction with the teacher. The verbal exchanges are, so far, not productive as they merely consisted of a pattern of questions and simple responses.

Through the "Explain-the-screen" orchestration, the teacher directed their attention to reading both y-values and x-values with respect to their respective labels and measurement units. After reading, Pansy and Bill became aware of their mistake as linking an independent variable to the label of x_1 (the number of old age cases) but in fact, they worked on x_2 (the number of ill health cases).

Table 9

Group discussion in a computing laboratory about a measurement unit

Excerpt	*Teacher/Student*	*Verbal contents*
53.	Teacher:	This is 12.09, right? How about this? 1% … 12.09%, ... This is not too large.
54.	Pansy:	Why?
55.	Teacher:	12.09 is not too large, why is it too large? OK, how do you interpret this figure?
56.	Pansy:	Ah!
57.	Teacher:	We are going to increase one unit of x. What is one unit of x?
58.	Bill:	Number of old age cases
59.	Bill & Pansy:	(Number of) ill health cases

The teacher recapped Pansy and Bill's correct answer as a feedback on the quality response of both students. Pansy gave a verbal response as well as an illustrative exposition of the value, 12.09 ("Sherpa-at-work" orchestration on their computer screen). The teacher modelled linking the value of regression slope to the measurement units and context of x_2 (the number of ill health cases) so that the data characteristics become more explicit. Pansy and Bill both understood and appreciated the teacher's interpretive framework. Pansy eventually keyed in the interpretation of a regression estimate associated with of x_2.

Table 9

Group discussion in a computing laboratory about a measurement unit

Excerpt	*Teacher/Student*	*Verbal contents*
60.	Teacher:	So, if we have one additional ill health case, …
61.	Pansy:	Yes.
62.	Teacher:	… The social security will be increased by 12.09 but this is not $12.09. This is in thousands, so (it) means twelve thousand and (nine hundred) something dollars.
63.	Pansy:	Oh! I see
64.	Teacher:	This is not too large. What it means is … you are going to spend $12090 for one (additional) ill health case.
65.	Bill & Pansy:	Oh! Okay.

To sum up, Bill and Pansy who had symmetric expertise attempting the regression tasks with concerted effort and took an active and dialogic role in the processes of reasoning and thinking. They utilized three types of student-centered orchestration in three different situations. Both "Discuss-the-screen" and "Spot-and-show" orchestrations were exploited when they programmed Excel and validated regression estimates respectively. However, they had trouble in the validation, so the teacher offered a structure for thinking (known as cognitive structuring) the interrelationship between the label, measurement unit, and numerical value of the data within the context of social security payment when using the "Explain-the-screen" orchestration. A complete interpretation with regard to the data measurement was developed after they had followed the teacher's cognitively structuring did an illustrative exposition of the value through the "Sherpa-at-work" orchestration. This observation further shows and substantiates Subsection 5.2.3, technology as a cultural tool when a student is learning with their teacher.

8. Questionnaire-based Survey after the Term Time

Data for this study were gathered by questionnaires after the students took a final examination including the ASM module and had received their overall assessment reports of the academic year. They were asked to complete the questionnaire and return it to their teacher via e-mail within a month. The questionnaire consisting of five open-ended questions so that students could give exhaustive answers and freely express what they had experienced when interacting with their learning partners and teacher in an IT environment. Students compared different aspects of learning, their learning progress, their learning process, the quality and quantity of interaction with their learning partner, the experience of working with their teacher between the ASM module and other statistics modules in the second year of their study: Economic and Social Statistics, Introduction to Statistical Theory, Market Research and Survey Sampling, Statistical Computing, and Operations Research (see Table 1 and Appendix 2).

A total of twenty-one fully completed questionnaires were received, i.e., the response rate is 38.2%. This is satisfactory as 20%-30% response rate is generally found in such mode of data collection. The survey findings are reported below under headings corresponding to the five survey questions.

8.1. Learning Progress when Working with Learning Partners

Among the 21 survey respondents, 85.7% reported positively toward socially organized learning in the ASM module and their responses were similar and summarized in the following. Many of them found they were offered opportunity to discuss with classmates and work with their learning partners in the ASM classes and so could offer mutual assistance in learning and problem-solving each other, clarifying misunderstanding and their questions were addressed specifically by their partner without asking their teacher which led to better group performance. They did not find any of these in other statistics classes because neither organization nor encouragement of discussion with classmates was made by other statistics teachers. Two survey respondents (9.5%) gave a neutral response, whereas only one (4.8%) found her learning progress was slower in the ASM module than in other statistics modules because time was spent on peer discussion.

8.2. The Process of Learning with Learning Partners

A total of twenty survey respondents (95.2%) found the process of learning with their learning partners in the ASM module better in various ways. They could co-construct knowledge and had more discussions with their partners. When they had different opinions, they were patient to learn and respect another's ideas. The learning process stimulated individual thinking and this led students to explore more about the matter when working with their partners. They experienced discussion which proved to be the motivation for responding each other's questions in ASM classes but not in other statistics classes. In other statistics modules, it took students time to become familiar with their classmates before discussion was held because they did not have fixed learning partners. Only one survey respondent (4.8%) found no difference in the process of learning with their partner between the ASM module and other statistics modules.

8.3. The Quality and Quantity of Interaction with Learning Partners

Two (9.5%) out of the 21 survey respondents found no difference in the quantity of interaction with their partner between the ASM module and other statistics modules and nineteen (90.5%) had more interactions with their learning partners in the ASM classes in different situations. When problems were encountered, they found they could be better solved with joint effort. They did not only grasp knowledge but experienced enhanced communications between themselves. Students did not usually have much interaction with classmates in other statistics modules because the classroom settings did not facilitate effective interactions.

A total of nine (42.8%) of the survey respondents found no difference in the quality of interaction with their partner between the ASM module and other statistics modules. Another twelve (57.2%) of survey respondents experienced a better quality of interaction with their partner in the ASM classes, they found solving statistical problems successfully and efficiently resulted from productive of interactions.

8.4. The Experience of Working with Teacher

Six (28.6%) of the survey respondents had similar experience with regard to working with the ASM teacher and other statistics teachers. Fifteen (71.4%) of the survey respondents had positive experience of working the ASM teacher. The ASM teacher was more conscious of each student's learning and understood more about their learning difficulty than other statistics teachers who were concerned with getting module delivery completed. He spent more time on, and was much more involved in student learning. He initiated and posed questions in order to develop clearer understanding of a problem setting and lead students' thinking toward a problem solution.

8.5. The Experience of Working in an IT Environment

Among the 21 survey respondents, six (28.6%) had similar experiences when working in an IT environment in the ASM module and other statistics modules. Fourteen (66.7%) respondents had positive experiences of working in an IT environment in the ASM module. In the ASM module, the atmosphere of learning with IT was relaxed because students were able to discuss with their learning partners, but this was not found in other statistics modules. Students found working in an IT environment in the ASM module enhanced students' understanding and aroused their interest in learning when the module moved on to difficult or abstract concepts. Within an IT environment, students had more interaction with the ASM teacher who utilized a case study to illustrate regression modelling so that students could follow and manage regression modelling alone. They could ask the ASM teacher questions and seek his immediate assistance. The ASM teacher orchestrated learning to spend time on different groups of students quite evenly, which was unlike other statistics teachers only responded to those students who raised questions. Students had less incentive to use IT in other statistics modules in which they were not motivated to think but were required to perform routine tasks. Only one (4.8%) student felt learning with IT in other statistics modules boring.

9. Conclusion

The model of integrating technology into statistics classroom was implemented with empirical justifications through the above observation and survey studies. The teacher showed the pedagogical expertise, when coupled with technological affordances, to tailor for specific learning objectives. He utilized instrumental orchestrations when calling attention to specific regression results. On the other hand, the students orchestrated the use of Excel in group work to understand statistical processes. Evidently, technology as a cultural tool created an inspiring learning environment in which students were impelled to make statistical enquiries and exploration. This finding is pretty much following Drijvers et al. (2010).

More importantly, the process of learning with technology was much to do with the organization of classroom activities to stimulate conditions for communication and discussion. The first observation study was in accord with Goos (2004) and Manouchehri (2004) and showed that the lesson held in the lecture theatre was socially constructed by the teacher, and the students were in the pursuit of statistical understanding. The teacher led a class discussion toward argumentation, hypothesizing, interpretation, and reasoning; students were inspired a high level of verbal exchanges to make their ideas available for comment, suggestion, and argument, thus generating a more comprehensive view. Some students volunteered to take an active and dialogic role in the processes of reasoning and thinking, some were less responsive but watched and listen attentively to classroom discussions. Nevertheless, the teacher was sensitive to individual student needs by inviting their participations or adjusting the learning pace or approaches.

In the second observation study, the teacher took up both facilitating and scaffolding roles in practice sessions during which the students worked in pairs at computers to accomplish learning tasks through verbal exchanges and social interactions. He facilitated student learning with the provision of learning resources where the students set their learning agendas and had more learning autonomy with less reliance on teacher-directed tasks; they exchanged personal views, shared information, insights as well as ideas, and offered mutual assistance when attempting learning tasks with the aid of Excel. Successful peer collaboration was under the influence of social environment in the laboratory with respect to positive interpersonal relationships with their partners. The teacher monitored and regularly intervened in their learning process. Both peer collaboration as well as student-teacher interaction were in the social context of learning within an IT environment; this echoes the opinion of Wegerif (2015).

In the second survey, the students commented that the ASM lessons were different from other statistics modules they took within the ASC program in the same academic year because the ASM classroom offered opportunities of mutual inquiry and contribution to learning through discussions rather than just listening. The ASM classroom operated differently from others they had experienced; the teacher organized students to engage with tasks, and encouraged students to work in groups after class. Through interaction with groupmates, they became more confident and capable. The survey results provided a complementary and more naturalistic perspective on students' experience of learning "with" discussion (in the ASM module) and "without" discussion (in other statistics modules studied in the same academic year).

All these four studies provide evidence of adaptation of teaching practices in the model of pedagogy in an IT environment suitable for classroom learning. These studies also show the conditions for stimulating discussions and promoting interaction among students and between students and teacher within the framework of the sociocultural theories of learning. More importantly, the observation studies substantiate the survey findings with a detailed account of peer collaboration, mutual assistance, and productive interaction in a process of discussion and teacher sensitivity to adjust the means of scaffolding assistance. Both observation studies are on one classroom and report on classroom interactions during the teaching of one module conducted within a relatively short period of time, but a series of observation studies conducted in the same classroom by the author of this paper and his colleague would substantiate the above findings (see for example, Li, 2015; Li & Goos 2018a, 2018b). The analysis of findings of survey data based on students' self-report may be prone to bias or may challenge its credibility.

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Appendix 1. *The project for enhancing collaborative learning*

Social context of learning took place beyond classroom settings because the original groups of students collaborated on regression modelling projects embedded in a real-life context around traffic and public transport, manpower resources, weather, water consumption, retail business, as well as import and export trades. The sets of relevant and official data consisting a dependent variable (y) and three independent variables (x_1, x_2, x_3) could be downloaded from the college computer server by the students. Through doing the project, they learnt to organize and connect previously accrued piecemeal statistical knowledge in an integrated manner. They discussed regression heuristics about how to formulate a regression problem with regard to how to use the given data, utilize proper statistical tools in Excel, evaluate the inferential force of evidence, and construct reasoned arguments. The discussions they held was sort of collective argumentation or a form of interaction where a student evaluated ideas his or her learning partner brought forward in order to come up with a joint decision leading to an answer. Yet, if they did not reach a consensus as a basis for joint progress, they sought the teacher's assistance. Through teacher scaffolding of the process of inquiry toward hypothesizing, interpretation, and reasoning, students gained an appreciation of their teacher as being an active and communicative participant in learning and their subsequent talk led to negotiation with learning partner about how to use statistical evidence to substantiate their reasoned arguments.

After completing the project, each pair of students presented their work in front of class in a computing laboratory session. Their classmates were attentive to the presentation but nobody challenged their work. To ensure a smooth presentation flow, students in each pair took turns in verbally reporting the formulation of project objectives, examination of data, construction and validation of model with sound justification, or practical implications of model while his or her learning partner was orchestrating the use of PowerPoint, Excel, and data projector for illustrating or substantiating specific arguments they wanted to make or responding the teacher's questions. The questions were to offer each presenter directives or an opportunity to elaborate, clarify, or defend reasoned arguments. When the teacher probed for incomplete or vague responses, his or her learning partner supplemented. The oral presentations were consistent with their written reports which mostly showed regression heuristics vividly, the students monitored interaction between regression models they built and the given data as well as assessed and validated the models. Both verbal and written presentations of their projects showed that each pair of students worked cooperatively after their class and peer collaboration presented an ideal context for promoting the development of statistical thinking associated with regression heuristics.

In order to reduce the extent of academic variability among the groups, a consideration of ability compositions in groups was taken. Thus, a less competent student was grouped with a more competent peer, the group is with asymmetric expertise, as enabling a more competent student to assist his or her less competent learning partner. These groups become more homogeneous in terms of students' academic abilities on the basis of their grade point averages achieved in their Year 1 Study; similar learning outcomes of the project will probably be achieved by different groups.

The teacher established a learning environment and fostered opportunities that facilitated peer learning. In the group projects, there were a series of interpersonal and communication skills used by the students when collaborating in formulating research objectives; exploiting and regulating statistical methodology; and reporting results as well as and a conclusion. They were responsible for directing their own projects, whereas the teacher provided supervision to students for developing skills of recognizing and solving problems.

Appendix 2. *Questionnaire*

Q1) How did your learning progress while working with your learning partner in the ASM module compare with your progress in other statistics modules you took?
Q2) How did the process of learning with your learning partner in the ASM module compare with the process of learning in other statistics modules you took?
Q3) How did the quality and quantity of interaction with your learning partner in the ASM module compare with interaction with students in other statistics modules you took?
Q4) How did the experience of working with your teacher in the ASM module compare with working with teachers in other statistics modules you took?
Q5) How did the experience of working in an IT environment in the ASM module compare with your IT experience in other statistics modules you took?