Cloud-based Versus Local-Based Web Development Education: An Experimental Study in Learning Experience

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Abstract

This paper investigates the use of a cloud computing environment to facilitate the teaching of web development at a university in the Southwestern United States. A between-subjects study of students in a web development course was conducted to assess the merits of a cloud computing environment instead of personal computers for developing websites. The goal of using cloud being to ensure that each student had access to the same high-quality learning experience. The study also sought to determine the extent to which cloud computing could ensure efficient use of students' time through eliminating hardware and software troubleshooting. Finally, the study sought to assess the extent to which the use of cloud computing would enhance students' learning experience.

Keywords: Web Development, Cloud Computing, Learning Experience, HTML, CSS, ASP.NET, C#

1. INTRODUCTION

The web development course considered in this study is taught in-person at the junior level and exists as a required course for students within the IS department in a business college. The college has a highly structured curriculum with a strong common core. As a result, there is a reliance on this course to meet specific learning objectives to prepare students for future courses. The first half of the course covers the fundamentals of HTML, CSS, and Javascript. The second half of the course requires students to install a complex Integrated Development Environment (IDE) and then build an e-business website that features a range of HTML and CSS components along with user interaction mechanisms including forms and a database.

Currently, instructors have students install web development software on personal computers and implement their projects in a standalone environment. Collectively, faculty have observed that student experiences with installing, configuring, and maintaining a web development platform on personal computers negatively impacts academic performance. One important drawback to this approach is that some students struggle to make the software operate on their computers. Time devoted to the installation is wasted as it detracts from learning objectives.

Faculty involved with the web course believe that cloud computing environments, which offer ubiquitous access to development systems, would improve student learning outcomes and satisfaction. Thus, the purpose of this study was to measure the potential difference in learning experience in a web development course between students with and without access to cloud-based services.

2. LITERATURE REVIEW

Web

Web design is an important topic in computer science and information systems academic programs and students gain significant leverage in the job market with related skills (Ellis, 2007, Sridharan 2004). There is a broad consensus in the literature on the difficulty of teaching web development. Deshpande & Hansen (2001) referred to web development as a discipline among disciplines as it draws together skills from areas such as business, computer science, and art.

Zhang & Dang (2015) suggest that difficulties with teaching web development result from needing to possess many skills beyond traditional programming using languages such as Java & C#. Web programmers also need skills which include server controls, data validation, site navigation, session validation, database, authentication and more. Del Fabro, de Almeida & Sluzarski (2012) offered three reasons for the difficulty of teaching web development which is 1) course content, 2) required infrastructure and 3) the environment of the university. The first two items reflect on the broad set of skills required by students and the required infrastructure to provide complex development environments for students' work. The third item argues that school often consists of many relatively trivial assignments that do not reflect complexities and dependencies students would face in real-world projects.

Connolly (2011) offered a review of computer science education literature. In the review, Connolly revealed that the most common approach to teaching web development in North America is to fit all needed material into a single upper-level course. The UK differs in that programs offer web develop as stand-alone degrees with topics divided into separate and distinct courses.

The literature regarding web development is consistent in demonstrating that there is much content to be taught/learned and that this content may be too much for a single course. The literature, particularly Zhang & Dang (2015) and Fabro, de Almeida & Sluzarski (2012), is also consistent in calling for a learning environment that includes not only web programming but also the related duties of a web developer including controls, database integration, authentication, data/session validation and much more.

Cloud

While cloud computing appears to be a relatively new concept, the technology was first introduced in the 1960s (Marston et al., 2011). The concept has surfaced in such forms as Application Management Services (AMS) and Application Service Providers. There is disagreement on the definition of cloud computing due to factors such as the approach taken (Prelas Kovacevic, Spoljaric, & Hegyi, 2012). In this paper we adopt the definition offered by the National Institute of Standards and Technology (NIST) which states:

"Cloud computing is typically presented as a service model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction."

NIST's five essential characteristics of cloud computing are useful: on-demand self-service, broad network access, resource pooling, rapid elasticity and measured service. The technology and cost improvements represented by cloud computing have led to the technology being called a "genuine information technology revolution" (Morrison, 2011). Conn & Reichgelt (2013) referred to cloud computing as the "fifth major paradigm shift in computing". IT experts predict that cloud computing will be the "dominant IT service delivery model" by the end of the decade (Jararweh et al., 2014).
Universities recognize the value of cloud computing (Mircea & Andreescu, 2011). The technological concept is ranked as one of the top priorities for higher education (Lowendahl, 2012). Sultan (2010) focused on the power of cloud computing to better utilize resources and reduce risk for academic institutions.

Ercan (2010) addressed not only the ability of cloud computing to offer cost savings to support university operations, but also benefits for students and academic programs. There are examples of cloud computing being adopted for specific courses or objectives such as Lawler and Joseph (2012) who used cloud computing in an entrepreneurship program and Chen et al. (2012)

who integrated cloud computing into a set of IS and CS courses.

Grossniklaus and Maier (2012) taught on the use of NoSQL and VoltDB in the cloud, and Mrdali (2011) offered an alternative Business Intelligence course using cloud technology to create a dynamic and cost-effective learning environment. Conversely, Lawler (2011) defined a more comprehensive and structured program that leverages cloud technology to provide an education platform for teaching CS and IS.

3. METHOD

A single, overarching research question guided the design of this study: *what is the potential difference in learning experience in a web development course between undergraduate students with access to cloud-based services compared to undergraduate students with access to local computing services only*? Operationally, learning experience appeared too abstract and did not adequately establish a measurable critical success factor. Based on research by (Schiefele, 1991), more measurable elements such as time, effort, errors, experience, and grades better served as critical success factors indicative of learning experience. Accordingly, we operationalized the general research question into five specific sub-questions (Table 1). Further, the five sub-questions then informed both the identification of the study variables as well as the selection of relevant questions for the data collection instrument.

Population
The population considered in this research was limited to four-year college students in the United States enrolled in a computer information systems or equivalent degree track. We assumed that members of the population engage in at least one quarter or semester of web development study. This assumption appeared rationale upon review of existing computer information systems and equivalent curricula. Further, we assumed that web development courses involved non-trivial coding work using Microsoft technologies (e.g., ASP.NET, C#). Based on the existing curricula surveyed, such an assumption appeared to be rational.

Sample
A self-selection sampling technique, using two steps, was employed. To avoid potential sampling bias, one of us not involved in teaching the web development course issued a call for participation. Students responding to the solicitation were permitted to self-select into one of two study groups (cloud-based versus local-based). We did not purposefully filter participants based on demographics. However, diversity across the institution and within the degree track under study facilitated a student population representative of the general population.

Table 1
List of Operational Research Questions

Index	Questions
1	What is the potential difference in the time spent installing and configuring the development environment between students using a cloud-based environment compared to students using a local environment?
2	What is the potential difference in the effort spent installing and configuring the development environment between students using a cloud-based environment compared to students using a local environment?
3	What is the potential difference in the number of errors arising during installation, configuring, and usage of the development environment between students using a cloud-based environment compared to students using a local environment?
4	What is the potential difference in normative experience installing, configuring, and using the development environment between students using a cloud-based environment compared to students using a local environment?
5	What is the potential difference in the final course grades earned by students using a cloud-based development environment compared to students using a local development environment?

Two factors bound the call for participation: (a) the scope as defined by the purpose of the research; (b) volunteers possessing characteristics of the broader population. Self-selection sampling was appropriate to segment potential volunteers from the researchers (Rutherford, 2006; Salkind & Rainwater, 2003). Segmentation (or blinding) was desirable to reduce participant selection time and to ensure adequate dedication to the study once enrolled (Salkind & Rainwater, 2003). Further, despite not having the power of probabilistic sampling techniques, self-selected sampling is effective when employing experimental research designs (Rutherford, 2006).

Twenty-nine students (out of 65 total) volunteered from two sections of an undergraduate web development course. The course is a core requirement for students in the computer information systems degree program and may serve as an elective for computer science majors. The course required ten weekly development projects, a midterm, and a final project. The weekly assignments were of increasing difficulty (ranging from simple HTML to single-page web applications) and included a web-based version of the classic game, hangman, using Microsoft ASP.NET with C#.

Fourteen participants joined the cloud-based study group with the remaining 15 selecting the local-based study group. Participants remained in the self-selected study groups for the duration of the course. The sample was independent because data from one group could not influence data from the other (Huck, 2012). Lastly, the sample size was appropriate given the scope and design of the research (Creswell, 2012; Huck 2012; Salkind & Rainwater, 2003).

Table 2
Breakdown of variables

Variable Index	Variable Name	Variable Type
I0	Cloud-based	Independent-Categorical
I1	Local-based	Independent-Categorical
D0	Time	Dependent-Ordinal
D1	Effort	Dependent-Ordinal
D2	Errors	Dependent-Ordinal
D3	Experience	Dependent-Ordinal
D4	Grade	Dependent-Ordinal

Study design
Analysis of the research questions indicated that a quantitative design would be necessary (Creswell, 2012). More specifically, because the research questions inquired how two independent groups might comparatively reveal the effect of treatment (Salkind & Rainwater, 2003), we used a between-subjects experimental design. Between-subjects design facilitates applying a treatment (i.e., change in development environment) to a study group while applying a different treatment to the second study group (Bellemare, Bissonnette, & Kröger, 2014). Additionally, the research questions outlined the study variables.

Variables
The study included a single independent variable (i.e., development environment) with two levels (i.e., cloud-based and local-based), and four dependent variables (Table 2). Independent variable levels aligned with the study groups and were categorical in nature. The five dependent variables were present in both study groups and typed as ordinal. Dependent variables served as data collection elements within the study instrument and formed a basis for hypothesis testing. There was a consideration for controlling potential extraneous factors such as prior experience with development tools or retaking the course after a failing grade. However, we decided that allowing for such factors more appropriately represented the general population and had equal probability of appearing in both groups.

Data Collection
Data were collected using a web-based questionnaire instrument. The instrument consisted of nine bounded questions and a single unbounded question designed to collect data aligned with the dependent variables. The bounded questions aligned with the dependent variables (Table 2). Six of the bounded questions were Likert items with the same scale. The Likert scale ranged from strongly agree, to neutral and strongly disagree. Three of the bounded questions were multiple-choice. All multiple-choice questions were of different response scales. The last question was unbounded to allow participants to submit unfiltered feedback, but data were used only as a measure of course feedback, not as data in this study's analyses. One of us who led the course sections paired study participants with each student's final course grade.

A pilot test validated the data collection instrument as reliable and internally valid. The pilot test included five participants. Pilot participants completed the questionnaire and submitted feedback to a brief set of meta-questions. The meta-questions included elements such as length of the study instrument, clarity of questions, and wording. Additionally, pilot data were used to validate the data analysis process.

Data analysis
The data were ordinal as such represent ordered categories (Huck, 2012). Interval and ratio data types were ruled out because the quantitative values collected were not equidistant (Sullivan & Artino, 2013) or inclusive of a true zero value (Jamieson, 2004). Moreover, since the Likert items and multiple-choice questions would be inferentially analyzed, we felt that treating such as ordinal would be appropriate (Lovelace & Brickman, 2013; Norman, 2010).

A two-phased data analysis procedure was used first to describe the data and then to test a (null) hypothesis using an inferential statistic. The research hypothesis was that students using a cloud-based service to host a web development environment would (a) spend less time installing and configuring the development environment; (b) expend less effort; (c) encounter fewer errors; (d) report a higher quality learning experience; (e) finish with higher course grades. Conversely, the null hypothesis considered in this study posited that students using a cloud-based service to host a web development environment would (a) spend the same or more time installing and configuring the development environment; (b) expend the same or more effort; (c) encounter the same or more errors; (d) report the same or a lower quality learning experience; (e) finish with equivalent or lower course grades. However, like with the research questions, we operationalized the general hypotheses into more specific, more testable statements (Table 3).

Table 3.
Summary of Operationalized Hypotheses

	Research Hypothesis Element	Null Hypothesis Element
Installing & configuring	HA_1 - Less time	$H0_1$ - Same or more time
Effort	HA_2 - Less	$H0_2$ - Same or more
Errors	HA_3- Less	$H0_3$ - Same or more
Learning experience	HA_4 - Higher quality	$H0_4$ - Same or lower quality
Grades	HA_5 - Higher	$H0_5$ - Same or lower

The Mann-Whitney U statistic was the appropriate inferential statistical to test the null hypotheses. The rationale for the decision included independence of study groups, data type (ordinal), and most importantly because the research questions required comparison of the two study groups (Huck, 2012; Salkind & Rainwater, 2003). Alternative statistical measures were not appropriate (e.g. Wilcoxon, Kruskal-Wallis) because of the number of study groups, uneven samples, and data type (McDonald, 2014).

4. RESULTS

Data were first analyzed using descriptive statistical techniques. Doing so permitted a general understanding of how participants engaged with the associated development environments. As well, the descriptive indicators facilitated quick, visual interpretation of the data. For readability, the descriptive results are organized in order of appearance on the data collection instrument.

The first question asked participants to estimate the total time spent downloading, installing, and configuring the development environment (Figure A1). The question was bounded, multiple-choice with six response options. Overall, the cloud-based group (between 554 and 1140 minutes total) described spending less time downloading, installing, and configuring the development environment compared to the local-based group (between 885 and 1260 minutes total). Further, the cloud-based group demonstrated a central tendency lower (Mdn_2 = 5 or 31-60 minutes) compared to the local-based group (Mdn_1 = 4 or 61-120 minutes). Overall, both groups demonstrated equal distribution of participants in the lowest response range (N = 4 at < 30 minutes) while the local-based group alone demonstrated more participants at the highest response ranges (N = 2 at 121 to 180 minutes; N = 1 at > 241 minutes).

The second question asked participants to gauge the level of effort or difficulty expended to download, install and configure the development environment (Figure A2). The question was bounded, multiple-choice, with three response options. Overall, the local-based study group described (Mdn_1 = 3 or Easy) the effort as easier compared to the cloud-based group (Mdn_2 = 2 or Moderate). Both groups demonstrated equal distribution at the most difficult selection option (N = 1 at Hard). However, the local-based group demonstrated a higher number of participants describing effort in the easiest selection option (N = 9 at Easy) compared to the cloud-based group (N = 4 at Easy). The inverse appeared for the middle selection option; local-based participants were few (N = 5 at Moderate) compared to cloud-based participants (N = 9 at Moderate).

The next question asked participants to select a level of agreement with the statement, my development environment contributed in a positive manner to my web development experience (Figure A3). The question was bounded and consisted of a five-element Likert scale. The two study groups differed in level of agreement by one degree according to central tendency: local-based participants agreed with the statement (Mdn_1 = 4) while the cloud-based group distributed between disagreement and neutral (Mdn_2 = 2.5). Collectively, more local-based participants gravitated towards agreement (*N* = 5 at Strongly Agree; *N* = 3 at Agree) while cloud-based participants grouped towards disagreement (*N* = 1 at Strongly Disagree; *N* = 2 at Disagree).

Next, participants offered a level of agreement with the statement; *I was able to complete my assignments without error because of my development environment* (Figure A4). The question was bounded and used a five-element Likert scale. Overall, local-based participants agreed with the statement (Mdn_1= 4) while the cloud-based group remained neutral (Mdn_2 = 3) again. Further, the two groups' responses were distributed similarly to the prior question insofar as the majority of local-based participants selected levels of agreement (*N* = 3 at Strongly Agree; *N* = 8 at Agree) compared to the cloud-based group converging towards levels of disagreement (*N* = 1 at Strongly Disagree; *N* = 4 at Disagree).

The fifth question was bounded and used a five-element Likert scale to collect participant level of agreement with the statement, my environment allowed for the efficient installation of development tools (Figure A5). The question was bounded within a five-element Likert scale. The local-based development environment study group predominantly agreed (Mdn_1= 4) while the cloud-based study group centrally distributed between neutral and agreement (Mdn_2 = 3.5). Both groups gravitated towards aggregate levels of agreement. However, cloud-based participants were more numerous across disagreement elements (*N* = 3 at Disagree; *N* = 1 at Strongly Disagree) compared to the local-based group (*N* = 1 at Disagree).

Participants selected a level of agreement with the development environment facilitating the efficient completion of coursework in the sixth question (Figure A6). The question used a five-element Likert scale and was bounded. Participants in the local-based development environment group generally agreed (Mdn_1 = 4). Moreover, more than one-third of individuals in the local-based study group (*N* = 6) described strong agreement with the statement. Comparatively, cloud-based participants were overall neutral (Mdn_2 = 3) but with equal distribution of individuals describing strong agreement (*N* = 4) as well as disagreement (*N* = 4).

The next question asked participants to select a level of agreement with the statement; I was able to rapidly build my web development environment (Figure A7). The question consisted of five agreement level options within a bounded Likert scale. Overall, the two study groups described identical levels of strong agreement (*N* = 4, each) and levels of agreement differing by one degree (*Mdn_1 = 4; Mdn_2* = 3). As well, strong disagreement levels were identical between groups (*N* = 1, each). On the other hand, a proportionally large number of participants in the local-based group selected a neutral level of agreement (*N* = 6) while few (*N* = 2) cloud-based participants did so.

The eighth question posed to participants inquired if learning was effective and efficient because of the associated development environment (Figure A8). The question was bounded and measured agreement across a five-element Likert scale. Members of the local-based study group centralized upon agreement (Mdn_1 = 4) whereas cloud-based participants tended to describe a neutral position (Mdn_2 = 3). Additionally, there were zero cloud-based participants present in the Likert scalar extremes. Conversely, the local-based study group was heavily represented across both agreement elements (*N* = 5 at Strongly Agree; *N* = 6 at Agree).

The last instrument question posed to study participants inquired about the number of errors encountered during the download, installation, and configuration of the development environment (Figure A9). The question was bounded and used a five-element multiple-choice scale. Overall, both groups described encountering errors. Local-based participants indicated a lower error incidence (Mdn_1 = 5 at between zero and one errors) compared to the cloud-based study group (Mdn_2 = 4 at between one and two errors). Furthermore, participants using a local-based development environment described encountering between 9 and 24 errors in total. In contrast, cloud-based participants described encountering between 20 and 34 total errors.

Participants across both study groups performed well with respect to final course grades (Figure A10). Participants in the local-based development environment group demonstrated a higher grade tendency (*Mdn*$_1$ = 4 or A) than the cloud-based group (*Mdn*$_2$ = 3.7 or A-). Furthermore, both groups aligned the tendency of the general student sample frame in the course sections used in this study.

Inferential Analysis
Inferential data analysis was used to measure the differences between the two study groups according to the research questions and hypotheses. The inferential test results are collated below according to such groupings. Furthermore, independent variables of cloud-based development environment group (i.e., Azure) and local-based development environment group were coded as CBDE and LBDE for readability.

Installing and configuration
We first analyzed data from two questions as a comparative measure the $H0_1$ hypothesis. Descriptive testing of question one indicated that the time spent installing and configuring the development environment was lower for the CBDE group (31-60 minutes) than for the LBDE group (61-120 minutes). However, the Mann-Whitney *U* was found to be 90.5 ($p > 0.05$) and so the null hypothesis could not be rejected (Table 4). Further, the results were not statistically significant

Table 4
Time downloading, installing, and configuring the development environment between groups

Ranks			
Group	*N*	Mean Rank	Sum of Ranks
CBDE	14	16.04	224.5
LBDE	15	14.03	210.5
Total	29		
Mann-Whitney U test results			
U	Z	*p*-value	*SD*
90.5	-0.611	0.542	22.91
Notes: Q1; p = 0.05 one-tailed; power at > .80			

Concurrently, we analyzed question five. Descriptive testing indicated that the LBDE and CBDE groups were close in estimating efficiency in installing development tools within associated environment. The Mann-Whitney *U* was 66 ($p > 0.05$) so the null hypothesis could not be rejected (Table 5). The results were not statistically significant.

Table 5
Efficient installation of development tools between groups

Ranks			
Group	*N*	Mean Rank	Sum of Ranks
CBDE	14	12.21	171
LBDE	15	17.6	264
Total	29		
Mann-Whitney U test results			
U	Z	*p*-value	*SD*
66	1.68	0.093	22.91
Notes: Q5; p = 0.05 one-tailed; power at > .80			

Effort
Secondly, we analyzed data from two additional questions as a comparative measure of the $H0_2$ hypothesis. Descriptive analysis of question two indicated that the effort expended to install and configure the development was greater for the CBDE group (Easy) than for the LBDE (Moderate). The Mann-Whitney *U* was 74 ($p > 0.05$) so the null hypothesis could not be rejected (Table 6). Moreover, the results of the test were not statistically significant.

Table 6
Effort expended to install and configure development environments between groups

Ranks			
Group	*N*	Mean Rank	Sum of Ranks
CBDE	14	12.79	179
LBDE	15	17.07	256
Total	29		
Mann-Whitney U test results			
U	Z	*p*-value	*SD*
74	1.331	0.184	22.91
Notes: Q2; p = 0.05 one-tailed; power at > .80			

In tandem, descriptive analysis of data from question seven, revealed similar information as question two. What is more, the Mann-Whitney *U* was 105 ($p > 0.05$). Such indicated that the null hypothesis, again, could not be rejected (Table 7). The results were not statistically significant though.

Table 7
Rapidity of building the development environment between groups

Ranks			
Group	*N*	Mean Rank	Sum of Ranks
CBDE	14	15	210
LBDE	15	15	225
Total	29		
Mann-Whitney U test results			
U	Z	*p*-value	*SD*
105	0.022	0.984	22.91
Notes: Q7; p = 0.05 one-tailed; power at > .80			

Errors
Next, we analyzed data from questions four and nine as a comparative measure of the $H0_3$ hypothesis. Question four revealed that the LBDE group agreed that group participants were able to complete assignments without error due to the local-based development environment while the CBDE group remained neutrally aligned. The Mann-Whitney *U* was 59 ($p < 0.05$) and would support rejection of the null hypothesis. The results (Table 8) were statistically significant.

Table 8
Completion of assignments without errors between groups

Ranks			
Group	*N*	Mean Rank	Sum of Ranks
CBDE	14	11.71	164
LBDE	15	18.07	271
Total	29		
Mann-Whitney U test results			
U	Z	*p*-value	*SD*
59	1.99	0.047	22.91
Notes: Q4; p = 0.05 one-tailed; power at > .80			

Analysis of question nine demonstrated a competing view of the comparison between study groups however. Descriptively, the LBDE study group reported fewer errors compared to the CBDE group. Yet, the Mann-Whitney *U* was 76.5 ($p > 0.05$) and would not support rejection of the null hypothesis (Table 9). Moreover, the results were statistically significant.

Table 9
Estimated number of errors during installation, configuration and use of development environments between groups

Ranks			
Group	*N*	Mean Rank	Sum of Ranks
CBDE	14	12.96	181.5
LBDE	15	16.9	253.5
Total	29		
Mann-Whitney U test results			
U	Z	*p*-value	*SD*
76.5	1.222	0.111	22.91
Notes: Q9; p = 0.05 one-tailed; power at > .80			

Learning experience
Penultimate hypothesis ($H0_4$) testing drew upon data from three questions. Question three descriptively indicated the LBDE group agreed that the environment contributed in a positive manner to the learning experience while CBDE participants vacillated between disagreement and neutrality. The Mann-Whitney *U* was 59 ($p < 0.05$) and data suggested that the null hypothesis could be rejected (Table 10). Furthermore, the results were statistically significant.

Table 10
Contribution of development environment to positive learning experience between groups

Ranks			
Group	*N*	Mean Rank	Sum of Ranks
CBDE	14	18.07	271
LBDE	15	11.71	164
Total	29		
Mann-Whitney U test results			
U	Z	*p*-value	*SD*
59	1.99	0.047	22.91
Notes: Q3; p = 0.05 one-tailed; power at > .80			

Next, we analyzed data from question six. Descriptive analysis demonstrated that the LBDE agreed that the development environment facilitated the efficient completion of coursework while the CBDE group trended between neutral and agreement. The Mann-Whitney *U* was 73.5 ($p > 0.05$). The null hypothesis could not be rejected based on these data. As well, the results (Table 11) were not statistically significant.

Table 11
Facilitation of coursework completion within development environments between groups

Ranks			
Group	*N*	Mean Rank	Sum of Ranks
CBDE	14	12.75	178.5
LBDE	15	17.1	256.5
Total	29		
Mann-Whitney U test results			
U	Z	*p*-value	*SD*
73.5	1.35	0.089	22.91
Notes: Q6; p = 0.05 one-tailed; power at > .80			

Lastly, descriptive testing of question eight found LBDE group members agreed that the learning experience was efficient and effective within the development environment whereas the CBDE was neutral. The Mann-Whitney *U* was 105 ($p > 0.05$). The null hypothesis could not be rejected. The results of the test were not statistically significant (Table 12).

Table 12
Efficiency and effectiveness of learning experience between groups

Ranks			
Group	*N*	Mean Rank	Sum of Ranks
CBDE	14	15	210
LBDE	15	15	225
Total	29		
Mann-Whitney U test results			
U	Z	*p*-value	*SD*
105	0.022	*0.984*	*22.91*
Notes: Q8; p = 0.05 one-tailed; power at > .80			

Grades
Final grades were collected directly from the course learning management system portals. Descriptively, data revealed that the LBDE group earned higher marks (A or 4.0) than for the CBDE group (A- or 3.7). The Mann-Whitney *U* was 53 ($p < 0.05$) and thus the null hypothesis could be rejected (Table 13). As well, the results were statistically significant.

Table 13
Earned grades between groups

Ranks			
Group	*N*	Mean Rank	Sum of Ranks
CBDE	14	11.29	158
LBDE	15	18.47	277
Total	29		
Mann-Whitney U test results			
U	Z	*p*-value	*SD*
53	2.247	0.024	22.91
Notes: p = 0.05 one-tailed; power at > .80			

5. CONCLUSIONS

This project was limited by the fact that students were able to choose between stand-alone computers and a cloud solution. As a result, the cloud solution did not take advantage of connecting to other Internet resources. Students completed the same web project whether or not they used the cloud or a personal computer. Future studies need to explore a rich connectivity environment in which students connect their website to other systems via the Internet.

Furthermore, student performance with the CBDE environment (Azure) demonstrated that students encountered greater difficulties than anticipated in gaining proficiency with the technology. If students had been given an introductory exposure to Azure, the outcome of this study may have changed dramatically. Just the fact that students knew they were in a metered environment seemed to cause students to be less playful with the system, which perhaps hindered students' learning processes. It will be important to determine whether the introductory exposure to the cloud should be in a prerequisite course, or an introduction to cloud computing within the web course.

Installation and configuration
The inability to reject the null hypothesis and the lack of statistical significance between the CBDE and LBDE participants revealed in question 1 was a surprise. Likewise, the greater efficiency of working on local machines was not expected.

Students in the class have been working with personal computers for years, however, for most in the CBDE group, this was their first experience with a cloud computing environment. Students' lack of familiarity with the environment may have led to inefficiencies.

It is reasonable to surmise that students with less capable personal computers, opted for the cloud computing environment and may, in fact, have had a better experience than would have been the case using their personal computers.

A discussion amongst faculty who teach the web course reveals that there are often between three and eight students who dedicate more than 240 minutes to installing and configuring their development environments in a given section of this class. So the outcome in this study is viewed as positive despite the inability of the results to discern variance between the CBDE and LBDE installation groups.

Future studies may need to include sections of the course in which students do not have the cloud option available and sections where the cloud service is the only option available to tease out the impact on students' time. Alternatively, perhaps a within-subjects design in which each student completes both scenarios will more fully assess the impact of differences in time consumption.

Effort

Question 2 reveals that the LBDE group met with less difficulty downloading, installing and configuring the development environment. The agreement in question 7 demonstrating that students in the LBDE group built their environments more rapidly was therefore not a surprise. Students familiarity with personal computers allows them to work effectively in this environment. Also, students in the CBDE group experienced connectivity difficulties at several points during the academic term that grew increasingly exasperating as deadlines drew near. Future studies will need to measure or control for connectivity issues to assess their impact.

This outcome raises the question if experience and time spent in cloud computing environments will allow students to gain a measure of effectiveness using the cloud that rivals current personal computer use. More effective training for students on the utilization of the cloud, coupled with increased time on tasks in the cloud, appear to be needed.

Errors

Questions 4 and 9 reveal that students in the LBDE group perceived they were better able to complete assignments without error and also reported fewer errors. This outcome was a surprise as the cloud operator specifically supported the IDE in use, and the environment was well suited to the IDE's installation.

One plausible explanation for the discrepancy lies with the connectivity issues that students experienced in the cloud group. Students' lack of familiarity with the system, coupled with erratic connectivity, may have caused students to believe their input did not register and the command to be repeated with undesirable outcomes.

Learning Experience

Question 3 results were significant and reveal that the LBDE group believed their learning environment better contributed to their learning experience. The results of questions 6 and 8, while not statistically significant, suggest the LBDE group also viewed their environment as better supporting the efficient completion of assignments and more effective and efficient learning experiences.

Learning experience results are perhaps the most troubling. Student confidence in the efficacy of their learning environment is of the utmost importance. A positive learning experience is critical to enhancing the utility of the cloud computing option to gain broad acceptance from students.

Grades

While the LBDE group earned significantly higher grades, it is also true that the class overall scored higher than normal and the distribution of scores was more consistent than typical sections of the course. The cloud environment is believed to be at least partly responsible for the higher and more consistent grades as students who may otherwise have struggled with an ill-equipped computer used the cloud instead. There also seemed to be a novelty factor that enamored students and may have led to increased time on task and therefore better grades.

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Appendix A

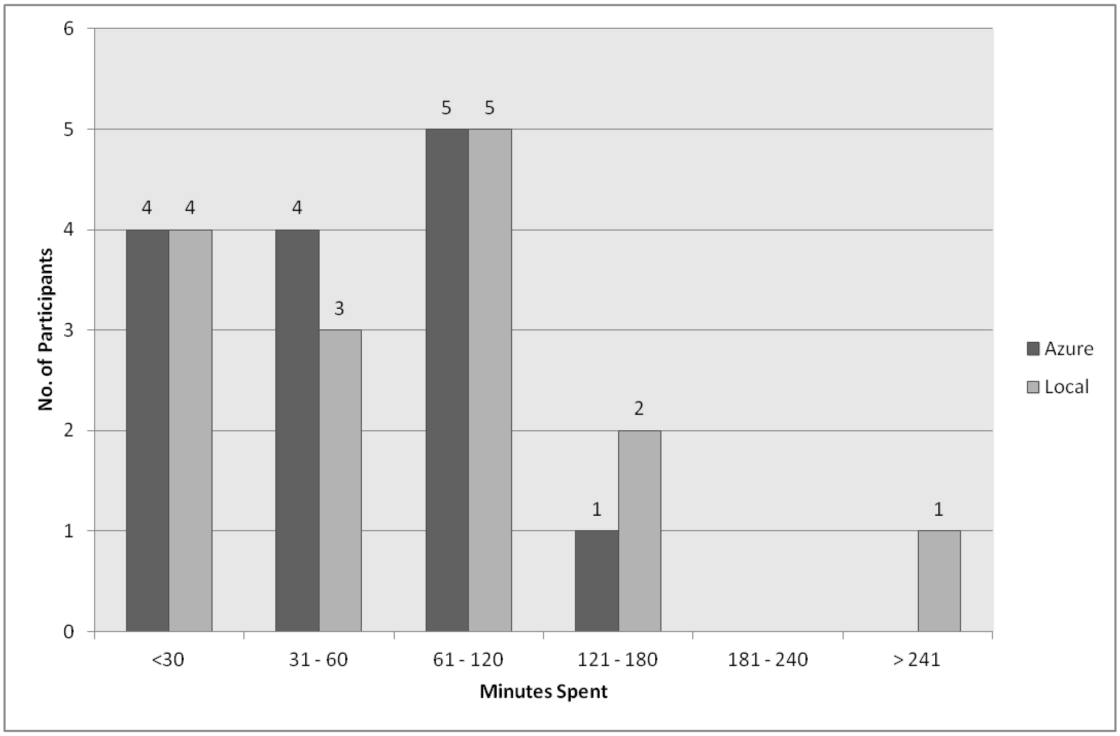

Figure 1. Minutes spent downloading, installing, and configuring development environments.

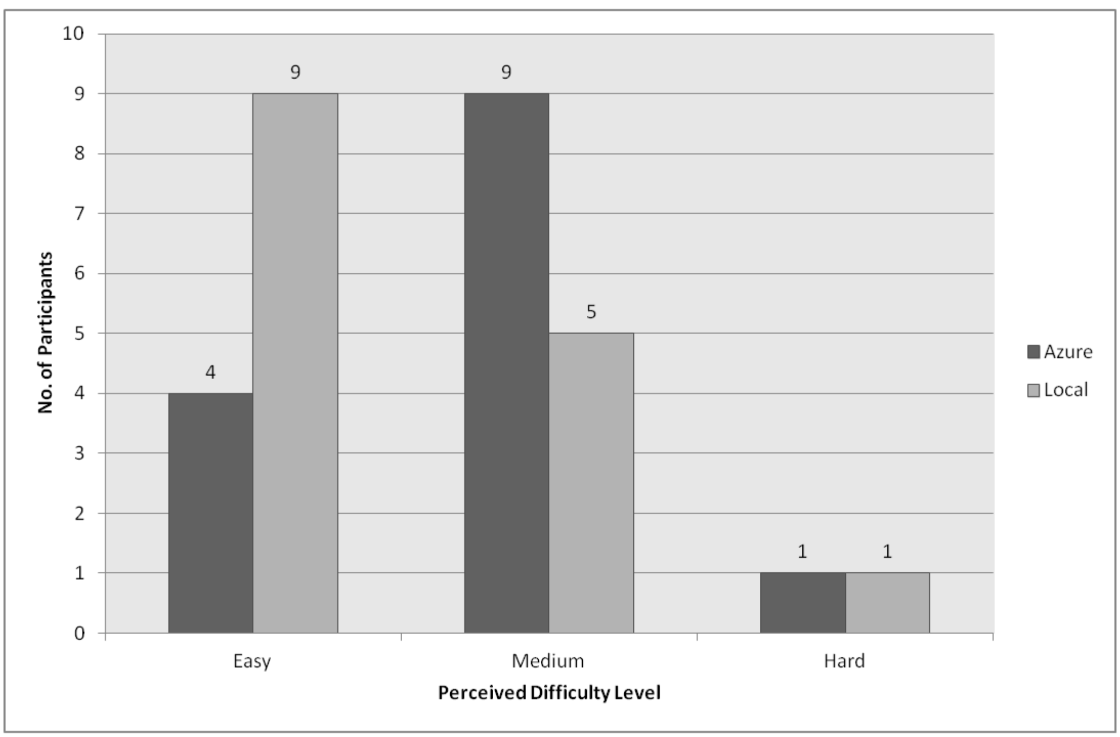

Figure 2. The perceived level of effort or difficulty downloading, installing, and configuring the development environment.

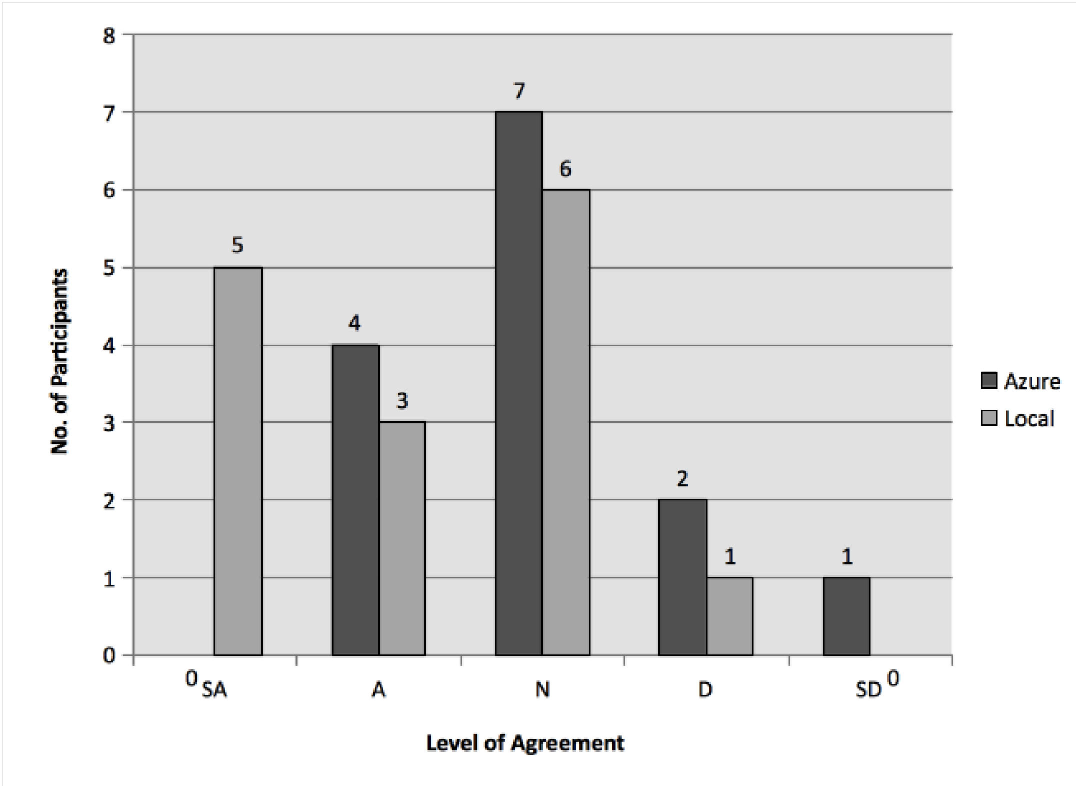

Figure 3. Participant level of agreement with the notion that the development environment contributed positively to the learning experience.

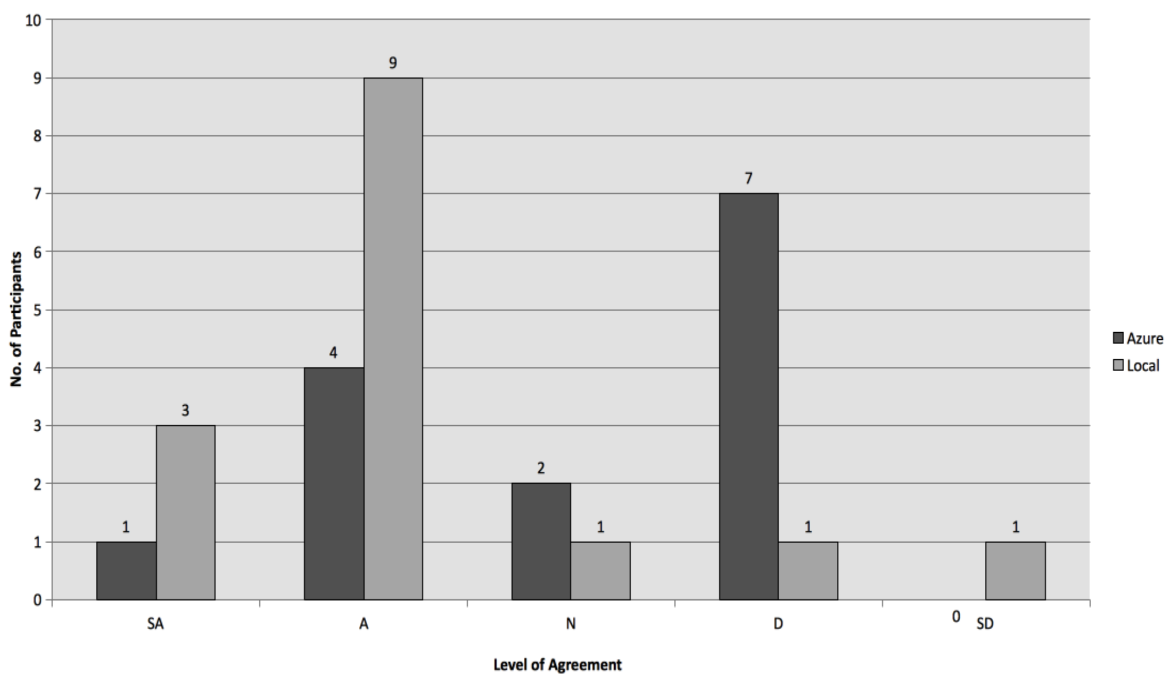

Figure 4. Participant agreement levels associated with the ability to complete assignments without error due to the development environment.

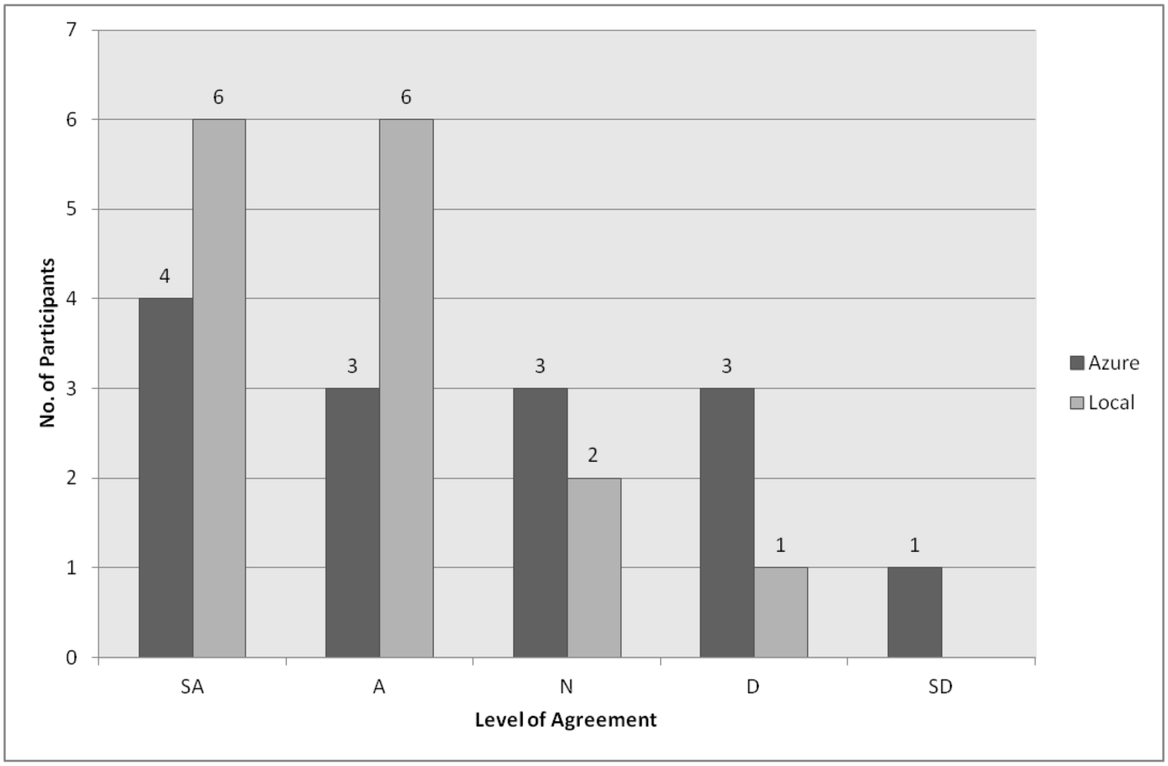

Figure 5. Participant level of agreement with level of efficiency in installing development tools within the associated group environment.

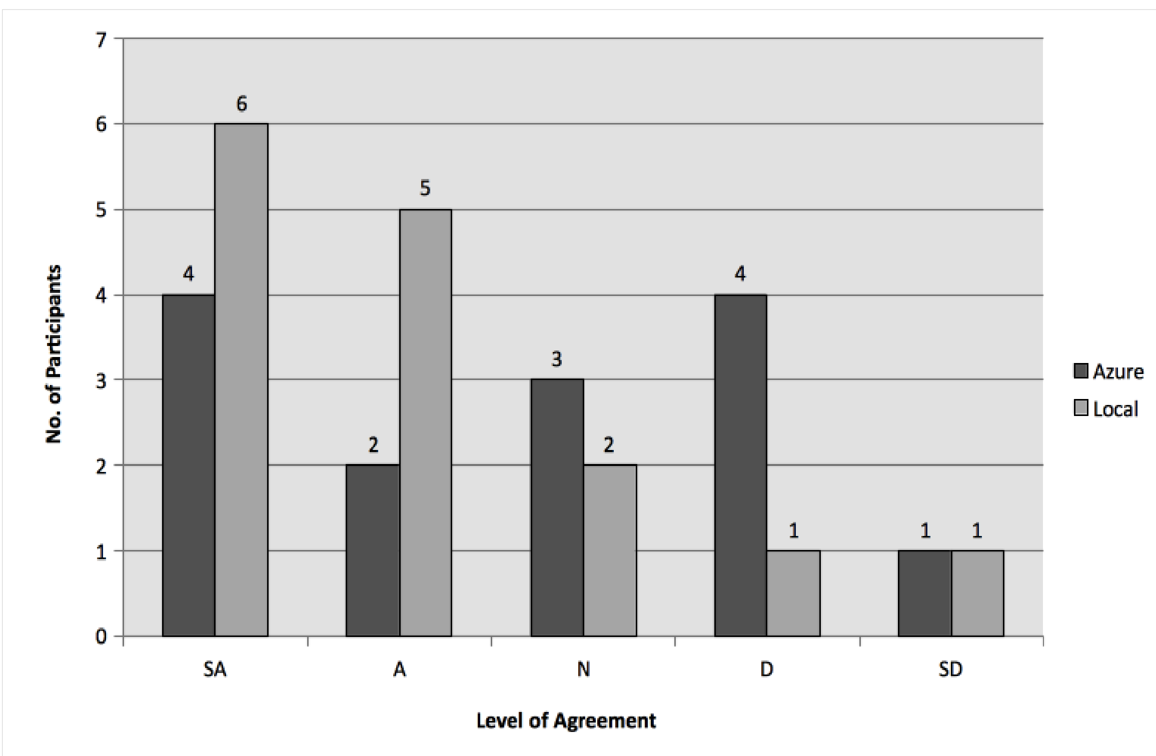

Figure 6. Distribution of participant levels of agreement with the development environment facilitating efficient completion of assignments.

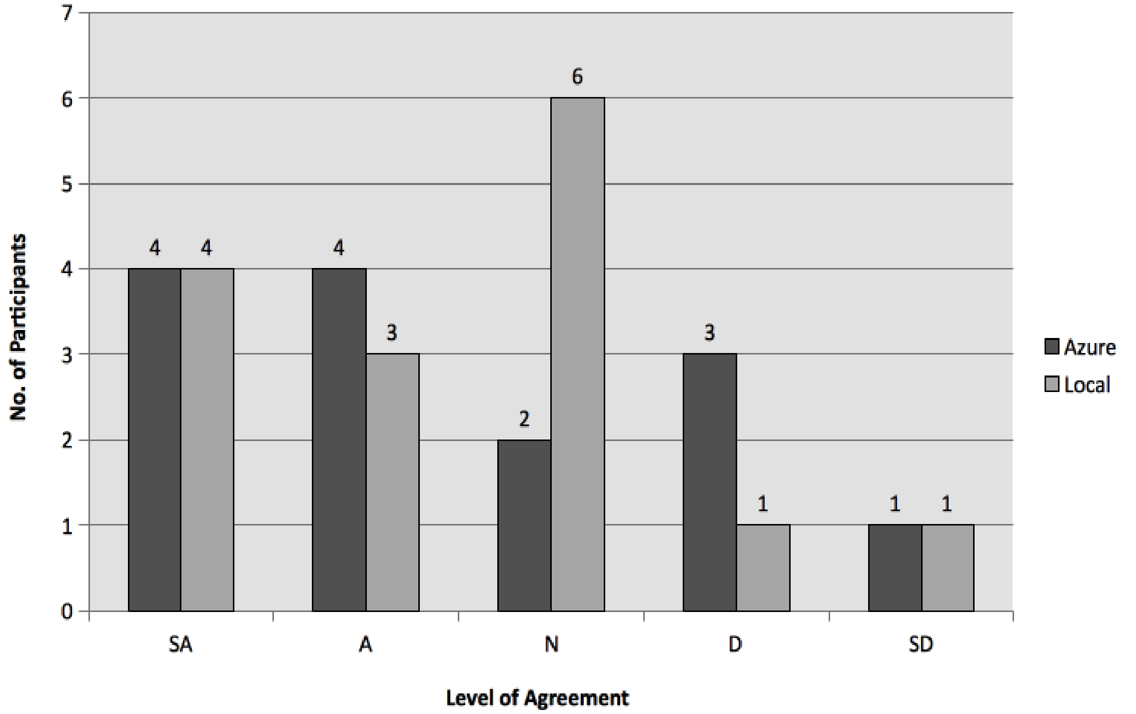

Figure 7. Participant levels of agreement with the notion that the associated development environment was built with rapidity.

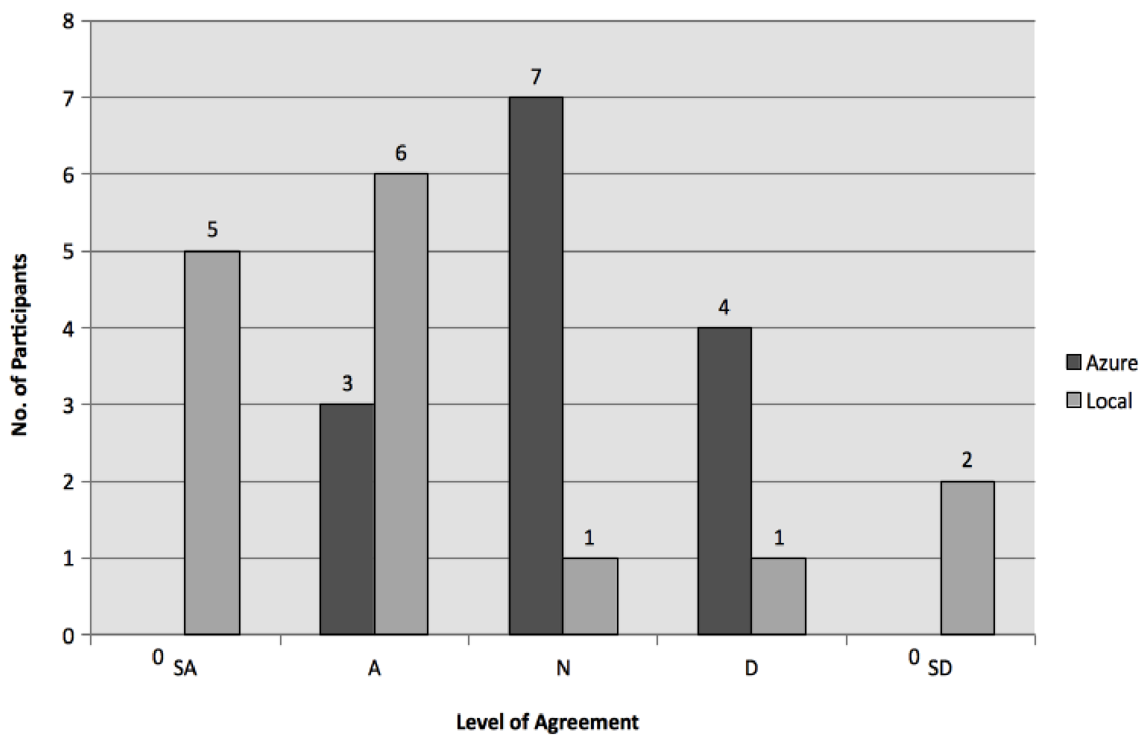

Figure 8. Participants' level of agreement relative to the development environment leading towards effective and efficient learning experiences.

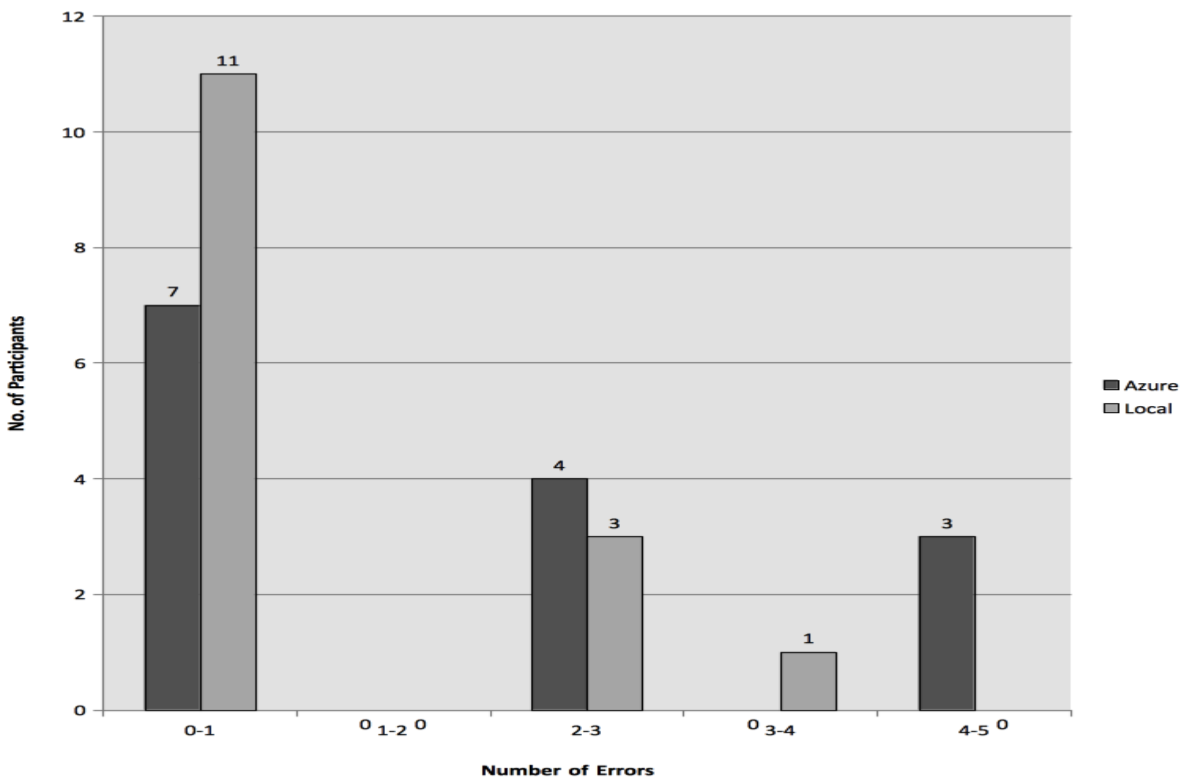

Figure 9. The number of errors encountered by participants during downloading, installation, and configuration of the development environment.

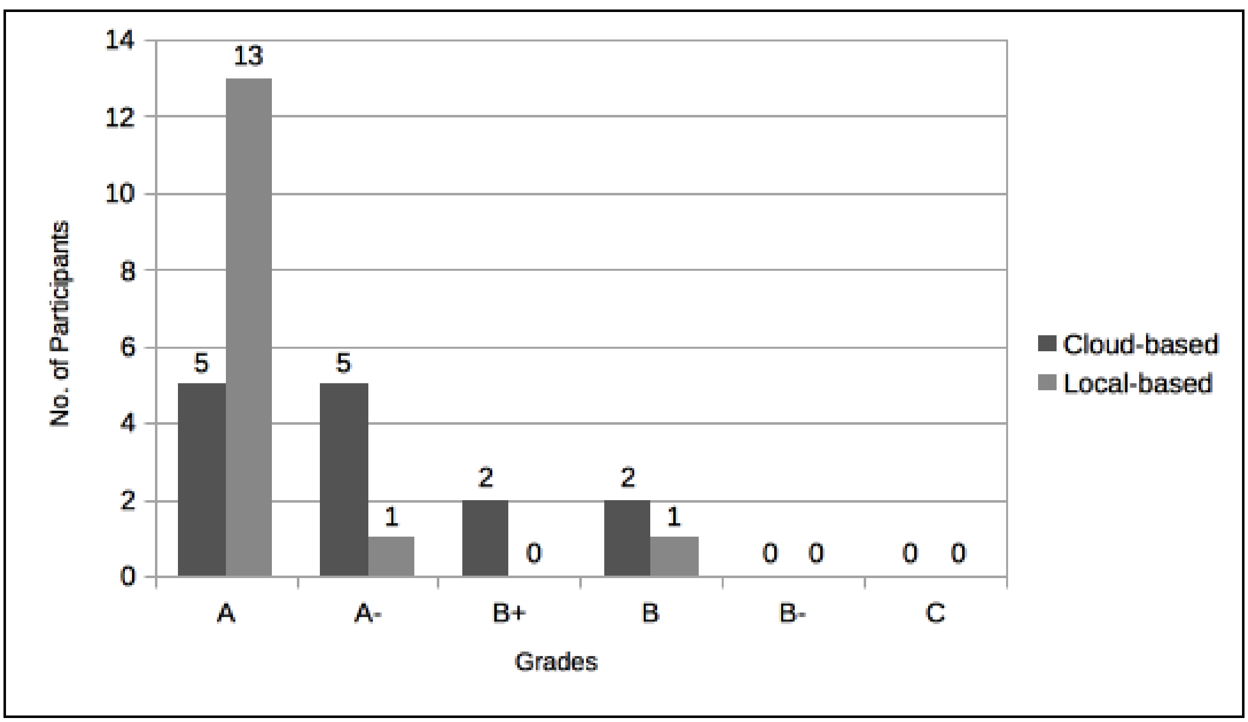

Figure 10. Distribution of final grades earned by participants using local-based development environments compared to cloud-based development environments.