Imagine you are working on a research paper about the **increase of technology in education and online learning**. Read the three information sources that follow this page and keep the CAARP model in mind as you review each source.

*Remember:*
- C = Currency
- A = Authority
- A = Accuracy
- R = Relevance
- P = Purpose

For the third and final source you will see the address (URL) of a website. Click on that link to be taken to a website. Please review the website as a whole for your third and final source.

To complete your assignment, go to: [http://library.uncw.edu/instruction/UNI_library_assignment](http://library.uncw.edu/instruction/UNI_library_assignment). Login at the bottom of the page and follow the directions to answer questions about each information source.
A comparison between paper-based and online learning in higher education

Lisa Emerson and Bruce MacKay

Lisa Emerson is an Associate Professor in the School of English and Media Studies at Massey University. Bruce MacKay is a Research Associate in the Institute of Natural Resources, Massey University. Address for correspondence: Dr Lisa Emerson, Massey University, English and Media Studies, Private Bag 11 222, Palmerston North, 4410, New Zealand. Email: L.Emerson@massey.ac.nz

Abstract
To date researchers have had difficulty establishing reliable conclusions in studies comparing traditional forms of learning (e.g., paper-based or classroom based) vs online learning in relation to student learning outcomes; no consistent results have emerged, and many studies have not been controlled for factors other than lesson mode. This paper compares the effects of presenting two versions of lessons on punctuation that differed only in their mode of presentation. 59 students completed a pre-lesson questionnaire, and after the lessons completed another questionnaire plus the NASA-TLX which tests subjective cognitive workload stress. The results showed that students who sat the lessons on paper performed 24% better than those who sat the lessons online. Reasons for this difference in learning outcomes are considered, but no clear reason is apparent in the data from this study. The study sounds a note of caution in terms of the move by tertiary institutions to online and/or blended learning, and suggests further studies are required which assess learning outcomes in different mode of learning.

Introduction
The movement in higher education to replace or supplement traditional pedagogical methods (e.g., paper-based or face-to-face learning) with online learning has seen considerable acceleration in the last few years, especially in relation to distance learning. While there is a body of research which compares web-based courses with traditional classroom-based courses (see, for example, Gal-Ezer & Lupo, 2002; Hughes, McLeod, Brown, Maeda & Choi, 2007; Meyer, 2003; Olson & Wisher, 2002; Toth, Fougl er & Amrein-Beardsley, 2008), no consensus has yet emerged on the impact of change of mode on student learning. Because one of the conventional methods of teaching distance and on-campus students is through study guides and other forms of paper-based instruction, the relationship between mode of learning and learning outcomes invites further exploration.

The advantages of online learning are clearly established: for example, web-based learning can be used to meet the needs of non-traditional students, leading to more open access to higher education (Mottarella, Fritz sche & Parrish, 2004), and allows more flexibility for learners (Allen & Seaman, 2006). Furthermore, in contrast to some other forms of learning, such as paper-based learning, online learning is seen as providing more interactivity—in relation to peers, tutors and the course material itself (Li, 2007)—and this interactivity is seen as having impacts on student learning and motivation.
Interaction transports the student to a new cognitive environment which motivates and activates the student ... . [it] promotes active engagement of students in the learning process and leads to improved academic achievement. (Katz & Yablon, 2002, p. 70)

Yet, the pace of change from traditional to online learning has not been embedded on firm evidence that online learning does, in fact, lead to better, or even equivalent, student outcomes or experiences (Toth et al, 2008), and recent work has sounded a note of caution. Njenga and Fourise (2008) for example, challenge the haste with which online learning is being promoted and adopted, commenting that ‘elearning in higher education ... is being created, propagated and channeled ... without giving educators the time and opportunity to explore the dangers and rewards of elearning on teaching and learning’ (p. 1). Their concerns are that the claims of elearning (for example, that it saves time and resources, and enhances student learning) are untested and that there are few voices expressing scepticism or researchers empirically testing these claims.

Certainly, the empirical studies which have tested the impact of different modes of learning on student learning suggest the need to pause and examine more carefully the impact of mode of learning on learning outcomes before tertiary institutions fully commit to a change of learning mode. The results of studies to date have been conflicting. Rivera and Rice (2002), for example, find no differences in outcomes for students enrolled in an online class, traditional face-to-face class, or web enhanced class. By contrast, research by Hughes et al (2007) and Maki, Maki, Patterson and Whittaker (2000) showed that web-based students outperformed students enrolled in a face-to-face class. Mottarella, Fritzse and Parrish (2004), Wang and Newlin (2000), and Waschull (2001); however, found that students enrolled in a web-based or web-enhanced class achieved lower grades than those enrolled in a traditional face-to-face classroom, even when the GPAs for the three groups were comparable. Mottarella, Fritzse and Parrish (2004) suggest that their findings may be a result of how learning is measured across these groups (ie by ‘declarative knowledge’) and suggest that other forms of assessment may yield different results. Newlin and Wang (2002) similarly call for more rigorous research to investigate web-based students’ outcomes.

It should be noted, however, that the studies discussed above relate to whole courses, which may be affected by multiple factors. For example, comparisons of whole courses conducted online or face-to-face cannot be assured that the content of both courses is identical: differences in emphasis or detail or explanation are inevitable. Similarly, the charisma, or otherwise, of a face-to-face teacher may impact on learning outcomes and hence on a comparative study. Another factor which may impact on the efficacy of online teaching is how, and to what extent, the instructor engages with the class on line. In such uncontrolled studies, mode of learning may be only one of several differences within the course being compared—and these multiple factors may explain the conflicting results of such studies.

By contrast, this study focuses on a single set of lessons which have been carefully designed to be identical in structure and content, and which differ only in their mode of delivery. This study is a comparison of the learning experiences and learning outcomes of students randomly allocated to a set of lessons on paper and online. In particular, it focuses on these questions:

- Did students studying online have more positive or negative learning experiences than those who studied the set of lessons online? Included in this is a measure of the workload stress experienced by the two different groups.
- Which of these groups achieved better mastery of the material, and how did these results correlate with students’ prior attitudes and expertise, experience of the set of lessons, and workload stress.

Method
An interactive online set of lessons on apostrophe usages, Interactive grammar! was developed using Chou’s (2003) model of interactivity (for more detail, see Emerson & MacKay, 2006). The programme covered three topics relating to apostrophe usage: contractions, simple possession and exceptional possession. Students were able to study a set of small lessons on each topic, and then engage with a formative test to test themselves on their proficiency before choosing to either study another lesson on the same topic, or move onto the next topic. In the formative tests, when student answers were incorrect, the student was provided with prompting questions plus the correct answer for each question. At the completion of the set of lessons, students were given a summative test of 25 randomly selected questions which covered all three topics; the results of this test were used as an indicator of mastery of the topic.

The online lessons were replicated as a paper-based study guide. The subject matter of the lessons ie punctuation, meant that the material could easily be adapted to a paper-based version because the material is almost entirely text based. The content and the structure of the study guide were identical to the online programme. Students were able to check their answers to all tests (except the final summative test) with an answer booklet which provided the same information as the online test answers. At the end of the paper-based lesson, students sat the same summative test as their online counterparts to assess their mastery of the material.

The trial we undertook involved 59 participants (85% female, 63% aged 18–26, 39 on-campus and 20 off-campus students), who were randomly allocated one of two tools—either the web-based tool Interactive grammar! or the paper-based study guide—to complete the full programme on apostrophe usage.

Procedure
Prior to starting the programme on apostrophes, participants completed a pre-test questionnaire which posed questions about their present attitudes to, and experience of, learning how to use apostrophes. Quantitative answers were assessed through a 1-to-7 Likert-type response scale; more qualitative data was collected through a series of open questions. In particular we wanted to assess students’ level of confidence and experience in using these skills before they undertook the lessons.

Students were then randomly allocated to one form of the study programme (either web or paper based). When they had completed the set of lessons, they were given a summative test to assess their mastery of the topic.

They then filled in two post-test questionnaires. The first sought feedback on the lesson through a series of questions using either a 1-to-7 Likert-type response scale or short answer qualitative responses. In particular we wanted to find out whether their confidence in using the skills had increased and to identify aspects of the lessons that they liked or disliked. The second post-test questionnaire focused on levels of cognitive workload stress.

Assessment of subjective cognitive workload stress
Workload stress was assessed using a paper-based form of the NASA-task load index (the NASA TLX), a measure of subjective cognitive workload stress. Noyes, Garland and Robbins (2004) define cognitive workload stress as ‘the interaction between the demands of a task that an individual experiences and his or her ability to cope with these demands. It arises due to a combination of the task demands and the resources that a particular individual has available’ (p. 111). The NASA-TLX assesses subjective workload as a function of a series of demands—mental, physical, temporal, performance, effort, and frustration (Luximon & Goonetilleke, 2001; Rubio, Diaz, Martin & Puente, 2004) which it presents on a series of indices. Various approaches have
been devised to measure objective workload, but subjective methods are still preferred, due to their ease of use, small cost and established efficacy. A number of instruments are available but we employed the NASA-TLX because generally the literature suggests it has more sensitivity than other measures such as SWAT (Subjective Workload Assessment Technique; see, for example, Rubio et al., 2004, or Charlton & O’Brien, 2002)

What we specifically wanted to know was whether the web-based lesson placed a higher cognitive workload on participants compared with a more familiar paper-based lesson. Researchers such as Bunderson, Inouye and Olsen (1989) and Clariana and Wallace (2002) who have investigated ‘test mode effect’, i.e., the concept that ‘identical paper-based and computer-based tests will not obtain the same result’ (p. 593), suggest that there is sufficient empirical data to establish that students respond differently to material on the web compared with material on paper, but both the actual causes and outcomes of those differences remain unclear. Our conjecture was that cognitive workload may be a factor in that difference. This conjecture is supported by the work of Noyes et al. (2004) who used the NASA-TLX to examine test mode effect and suggested that ‘computer-based tests required more effort than the paper-based ... test’ (p.112). This finding was also supported by our earlier study (Emerson & MacKay, 2006).

Responses on the Likert-type scales and the NASA-TLX workload index were analysed by the Kruskal-Wallis test using the non-parametric procedure NPAR1WAY of SAS (SAS Institute, 2001). Performance in the summative test was analysed using the analysis of variance procedure of SAS while the relationship between summative test scores and the NASA-TLX workload scores was examined using the linear regression procedure REG. As preliminary analyses revealed no significant differences between gender within groups and between modes or study location for any of the variables measured, the data were pooled over gender and location for the analysis.

Results

In general, students allocated to both lesson modes were positive about their current understanding of grammar and punctuation prior to undertaking the programme on apostrophe usage (Table 1). The groups showed no significant differences in response to punctuation usage, in terms of having been taught these skills, and being confident in their use of punctuation in general, and their attitudes towards the importance of good punctuation. They displayed similar levels of confidence in terms of grammar, punctuation and apostrophe usage.

The only significant difference between the two groups was that students in the paper-based mode agreed more strongly than their web-mode counterparts that they had mastered punctuation skills at high school (Table 1).

Students in both groups were equally very positive about their experience and perceived understanding of the lesson material (Table 2). The lessons themselves were regarded positively in terms of their structure, design and approach, and students, in both lesson modes, were positive with the notion that they had a better understanding of apostrophe usage having completed the lesson.

However, analysis of the students’ scores of the summative test revealed that students in the paper mode performed about 24% better than their web-mode colleagues (23.2/25 vs. 16.9/25; Table 3).

Mean NASA-TLX scores for students in the web mode were similar to those in the paper mode (Table 3) as was the range of NASA-TLX scores for both lesson modes (Figure 1).

While there were no differences in mean workload stress between the two lesson modes, the relationship between mastery result and workload stress differed. For the paper lesson mode, increasing workload stress had negligible impact on performance until about a NASA-TLX score...
of about 12 after which there was rapid decline in performance (Figure 1). In contrast, there was a steady and significant decline in performance of students who had done the web-based lesson with increasing workload stress across the entire range of stress scores encountered (test score \(= 19.76–0.37 \) [NASA-TLX score]; \(R^2 = 0.25, F[1, 26] = 8.84, p < 0.006\)).

**Discussion**

The results of the pre-test suggest that the two groups were sufficiently similar to allow robust comparison. Only one measure showed significant difference: the extent to which the students

<table>
<thead>
<tr>
<th>Question</th>
<th>Lesson mode</th>
<th>(\chi^2)</th>
<th>(p)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I was taught the conventions of grammar and punctuation at primary school</td>
<td>Paper 5.2, Web 5.0</td>
<td>0.005</td>
<td>0.944</td>
</tr>
<tr>
<td>I feel I mastered these skills at primary school</td>
<td>Paper 4.5, Web 4.1</td>
<td>0.538</td>
<td>0.463</td>
</tr>
<tr>
<td>I was taught the conventions of grammar and punctuation at high school</td>
<td>Paper 4.7, Web 5.0</td>
<td>0.633</td>
<td>0.426</td>
</tr>
<tr>
<td>I feel I mastered these skills during my time at high school</td>
<td>Paper 5.2, Web 4.4</td>
<td>3.917</td>
<td>0.048</td>
</tr>
<tr>
<td>I feel very confident about my ability to use correct grammar</td>
<td>Paper 5.3, Web 4.9</td>
<td>2.479</td>
<td>0.115</td>
</tr>
<tr>
<td>I feel very confident about my ability to use the correct conventions of punctuation</td>
<td>Paper 5.3, Web 5.0</td>
<td>0.694</td>
<td>0.405</td>
</tr>
<tr>
<td>I understand how to use apostrophes and feel that I employ them correctly most of the time</td>
<td>Paper 5.5, Web 5.4</td>
<td>0.125</td>
<td>0.724</td>
</tr>
<tr>
<td>I think the ability to use correct grammar and punctuation is important</td>
<td>Paper 6.6, Web 6.2</td>
<td>0.055</td>
<td>0.814</td>
</tr>
</tbody>
</table>

**Table 1: Mean scores\(^z\) for pre-test questionnaire**

\(^m\)Not significant.
\(^*\)Significant \((p < 0.05)\).
\(^z\)Likert-type scale from 1 (strongly disagree) to 7 (strongly agree).

<table>
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<tr>
<th>Question</th>
<th>Lesson mode</th>
<th>(\chi^2)</th>
<th>(p)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I feel that I understand the rules of apostrophe usage for contraction having completed this lesson</td>
<td>Paper 6.3, Web 6.3</td>
<td>0.058</td>
<td>0.809</td>
</tr>
<tr>
<td>I feel that I understand the rules of apostrophe usage for possession at the completion of this lesson</td>
<td>Paper 6.2, Web 6.0</td>
<td>1.099</td>
<td>0.294</td>
</tr>
<tr>
<td>I found the lessons clear and easy to understand</td>
<td>Paper 6.3, Web 6.3</td>
<td>0.355</td>
<td>0.551</td>
</tr>
<tr>
<td>I could see where I was having problems understanding and applying the material</td>
<td>Paper 5.9, Web 5.7</td>
<td>0.956</td>
<td>0.328</td>
</tr>
<tr>
<td>It was easy to find my way around the lessons</td>
<td>Paper 6.1, Web 6.5</td>
<td>1.592</td>
<td>0.207</td>
</tr>
<tr>
<td>I thought the lessons were fun</td>
<td>Paper 5.3, Web 5.6</td>
<td>0.514</td>
<td>0.462</td>
</tr>
<tr>
<td>The structure of the lessons (lesson &gt; try it out &gt; test) worked well in terms of aiding my learning</td>
<td>Paper 6.4, Web 6.3</td>
<td>0.416</td>
<td>0.519</td>
</tr>
<tr>
<td>I would recommend these lessons to anyone else who was having trouble with apostrophes</td>
<td>Paper 6.4, Web 6.4</td>
<td>0.055</td>
<td>0.814</td>
</tr>
</tbody>
</table>

**Table 2: Mean scores\(^z\) for post-test questionnaire**

\(^m\)Not significant.
\(^z\)Likert-type scale from 1 (strongly disagree) to 7 (strongly agree).
had mastered these skills at high school, perhaps suggesting that the paper-based group had longer-standing confidence in the use of punctuation. However, present levels of confidence were similar between both groups (Table 1).

The most outstanding result of this study is that students’ learning outcomes (as measured by the summative test; Table 3) for the paper-based lessons are significantly higher than those for the online lessons. The reasons for this outcome need to be examined.

First, this finding cannot be attributed to students’ prior learning or confidence or the time taken to complete the lesson. Regardless of prior learning or confidence levels or time on task, students studying the paper-based lesson achieved higher mastery scores than those studying the lessons online (Table 3).

Second, we considered whether there some aspect of mode of delivery that affects the differences in learning outcome. We tested a number of hypotheses, but were unable to come to a clear conclusion. Our first hypothesis was that one mode of delivery had higher levels of workload.

### Table 3: Analysis of work stress index and mastery test scores and lesson duration

<table>
<thead>
<tr>
<th>Variable</th>
<th>Paper</th>
<th>Web</th>
<th>Statistical criterion</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Work stress (NASA-task load index score)</td>
<td>7.79</td>
<td>7.87ns</td>
<td>0.004²</td>
<td>0.950</td>
</tr>
<tr>
<td>Summative test score (/25)</td>
<td>23.2</td>
<td>16.9</td>
<td>1.46y</td>
<td>0.0001</td>
</tr>
<tr>
<td>Time taken to complete lesson (min.)</td>
<td>32.2</td>
<td>27.4ns</td>
<td>6.46y</td>
<td>0.139</td>
</tr>
</tbody>
</table>

nsNot significant.
yLeast significant difference0.05,52.
²Kruskal-Wallis test.

![Figure 1: Relationship between work stress index (NASA-task load index score) and summative test score](image)

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stress which caused the difference in learning outcomes. However, this is not supported by the data (Table 3). Certainly, this study suggests that increases in workload stress correlated with poorer learning outcomes—but this applied to both learning modes. Noyes et al (2004) and Emerson and MacKay (2006) both suggest that the online material may require more effort than the paper-based material. However, the findings on workload stress in this study do not support this hypothesis: the range of workload stress was similar for both groups (Figure 1).

Next, we hypothesised that students sitting the online version of the lesson might engage with the material differently than those who were sitting the lesson on paper: that online tests may be perceived by students in the same light as, for example, social networking quizzes (which are common in forums such as Facebook) which might mean that students would not reflect to the same level, or for the same length of time, as those engaged with the paper-based lessons (because paper-based quizzes are more likely to be associated with formal educationally based tests). In other words, did the online students treat the lesson more like an online game or social quiz? Such speculation is supported by the arguments of researchers such as Mehlenbacher, Miller, Covington and Larsen (2000) who caution that ‘in our desire to promote active learning, we may be guilty of promoting more interactive learning environments, environments that give immediate responses to students but that do not necessarily facilitate reflection or a careful consideration of all the materials and tasks’ (p. 177).

If this were the explanation for the significant differences in learning outcomes—if instant feedback and interactivity causes the student to engage less deeply—then we would need, as teachers, to consider how to counteract this tendency. However, support for this hypothesis from this study is not strong. The quantitative results show no significant difference between the two groups in terms of how much they agreed with the statement that the lessons were ‘fun’ (Table 2), and there was no difference in terms of how long students took over the lessons (Table 3). However, the qualitative feedback was arguably more expressive and enthusiastic from the online version, and, interestingly, some of the students who sat the paper-based lessons recommended that the lesson be placed online:

This format of multichoice questions would be better on a computer. Answers could be marked automatically.

Using different mediums (such as multimedia or web-based programs) may help people struggling with the subject.

In this study, however, the notion that interactivity mitigated against deep learning was a weak hypothesis and would need further investigation.

One other possible explanation for the difference in learning outcomes between the two groups may lie with the way we assess student learning in relation to online learning. Mottarella et al comment:

Perhaps neither standardized tests nor grades capture the strengths that may be present in web-based pedagogy. It is therefore possible that course grades and standardized achievement scores will need to be supplemented with other measures un order to best capture what web instruction has to offer in terms of student learning outcomes ... web instruction may facilitate more active learning and deeper and critical thinking applied to course material and result in improved ability to apply course content to novel situations ... . (Mottarella, Fritzche and Parrish, 2004, p. 54)

Because we used standardised testing in this study, it is not possible to test this hypothesis. However, this suggests further research, using a range of assessment methods, may be necessary.

A further issue, suggesting a quite different line of further enquiry, is the possibility that the interactivity within the online version of the set of lessons (which was limited only to formative quizzes) was too limited and did not fully take advantage of the full range of interactivity presented by online learning environments. It may be that a wider range of interactive features may have strengthened the online version.
Linked to this is the notion that the subject matter of the lesson used in this study, ie punctuation, which lends itself to text-based instruction, may have advantaged paper-based instruction over web-based instruction because such a topic cannot make use of the more interactive or more sophisticated instruction methods available in web-based instruction, eg use of video and web-based social interaction. A comparative study of a lesson based on a different subject, eg the study of physiology, which could incorporate more complex web-based instruction methods which could not be replicated in paper-based form (eg multi-layered diagrams and/or videos of dissection), or a multi-disciplinary subject that required the kinds of social interaction possible online, might yield quite different results.

However, in such instances, an exact comparison of mode, using identical subject matter and structure, could not be achieved; which raises the questions of whether an empirical comparative study such as this, which may not be able to employ the distinctive advantages of both modes of instruction, is the best way to evaluate the strengths of online versus paper-based instruction.

Conclusions

These latter concerns raise multiple questions: how can we effectively measure the impact of model of learning on learning outcome? Is it possible—or desirable—to separate lesson mode from the content and structure of instruction? And what is the impact of the subject of the lesson on the desirability of mode of instruction?

Clearly, on a number of levels, the results of this study should lead us to further investigation of the impact of learning mode on learning outcomes, using a range of methods and subjects. Does online learning achieve better or equal results in relation to student learning outcomes in comparison with more traditional modes of learning—and does this differ across subject? How can we effectively answer this question? And how can we harness the strengths of both online learning, with its increased opportunities for interactivity, and the more traditional forms of learning?

Another area for future research concerns the ways in which students engage with online learning. In particular, we need to consider and extend Mehlenbacher, Miller, Covington and Larsen’s (2000) discussion of whether instant interactivity works against deep learning, or whether a web environment, which may be associated with online games and other social modes of activity, means students engage less intensively with learning material. If this is impacting on how students learn online, then we need to find ways to counteract this tendency. We may also need to consider the possibility that different forms of interactivity may impact on learning outcomes differently, and develop empirical approaches to testing this hypothesis. Furthermore, it would be useful to conduct further study into Mottarella, Fritzche and Parrish’s (2004) contention that other forms of assessment may be needed to determine the strengths of online learning.

In the meantime, we sound a note of caution concerning the rapid move of institutions of higher education towards online instruction. Until we have a clearer picture of the impact of learning mode on student learning outcomes, we need to consider how best to develop teaching and learning strategies that incorporate the strengths and opportunities presented by online learning with the strengths of more traditional modes of learning. And central to this exploration must be the enhancement of our students’ learning outcomes.

References


Towards the end of the summer of 1969 n a few weeks after the moon landings, a few days after Woodstock, and a month before the first broadcast of Monty Python's Flying Circus n a large grey metal box was delivered to the office of Leonard Kleinrock, a professor at the University of California in Los Angeles. It was the same size and shape as a household refrigerator, and outwardly, at least, it had about as much charm. But Kleinrock was thrilled: a photograph from the time shows him standing beside it, in requisite late-60s brown tie and brown trousers, beaming like a proud father.

Had he tried to explain his excitement to anyone but his closest colleagues, they probably wouldn't have understood. The few outsiders who knew of the box's existence couldn't even get its name right: it was an IMP, or "interface message processor", but the year before, when a Boston company had won the contract to build it, its local senator, Ted Kennedy, sent a telegram praising its ecumenical spirit in creating the first "interfaith message processor". Needless to say, though, the box that arrived outside Kleinrock's office wasn't a machine capable of fostering understanding among the great religions of the world. It was much more important than that.

It's impossible to say for certain when the internet began, mainly because nobody can agree on what, precisely, the internet is. (This is only partly a philosophical question: it is also a matter of egos, since several of the people who made key contributions are anxious to claim the credit.) But 29 October 1969 n 40 years ago next week n has a strong claim for being, as Kleinrock puts it today, "the day the infant internet uttered its first words". At 10.30pm, as Kleinrock's fellow professors and students crowded around, a computer was connected to the IMP, which made contact with a second IMP, attached to a second computer, several hundred miles away at the Stanford Research Institute, and an undergraduate named Charlie Kline tapped out a message. Samuel Morse, sending the first telegraph message 125 years previously, chose the portentous phrase: "What hath God wrought?" But Kline's task was to log in remotely from LA to the Stanford machine, and there was no opportunity for portentousness: his instructions were to type the command LOGIN.

To say that the rest is history is the emptiest of cliches n but trying to express the magnitude of what began that day, and what has happened in the decades since, is an undertaking that quickly exposes the limits of language. It's interesting to compare how much has changed in computing and the internet since 1969 with, say, how much has changed in world politics. Consider even the briefest summary of how much has happened on the global stage since 1969: the Vietnam war ended; the cold war escalated then declined; the Berlin Wall fell; communism collapsed; Islamic fundamentalism surged. And yet nothing has quite the power to make people in their 30s, 40s or 50s feel very old indeed as reflecting upon the growth of the internet and the world wide web. Twelve years after Charlie Kline's first message on the Arpanet, as it was then known, there were still only 213 computers on the network; but 14 years after that, 16 million people were online, and email was beginning to change the world; the first really usable web browser wasn't launched until 1993, but by 1995 we had Amazon, by 1998 Google, and by 2001, Wikipedia, at which point there were 513 million people online. Today the figure is more like 1.7 billion.

Unless you are 15 years old or younger, you have lived through the dotcom bubble and bust, the birth of Friends Reunited and Craigslist and eBay and Facebook and Twitter, blogging, the browser wars, Google Earth, filesharing controversies, the transformation of the record industry, political campaigning, activism and campaigning, the media, publishing, consumer banking, the pornography industry, travel agencies, dating and retail; and unless you're a specialist, you've probably only been following the most attention-grabbing developments. Here's one of countless statistics that are liable to induce feelings akin to vertigo: on New Year's Day 1994 n only yesterday, in other words n there were an estimated 623 websites. In total. On the whole internet. "This isn't a matter of ego or crowing," says Steve Crocker, who was present that day at UCLA in 1969, "but there has not been, in the entire history of mankind, anything that has changed so dramatically as computer communications, in terms of the rate of change."

Looking back now, Kleinrock and Crocker are both struck by how, as young computer scientists, they were simultaneously aware that they were involved in something momentous and, at the same time, merely addressing a fairly mundane technical problem. On the one hand, they were there because of the Russian Sputnik satellite launch, in 1957, which panicked the American defence establishment, prompting Eisenhower to channel millions of dollars into scientific research, and establishing Arpa, the Advanced Research Projects Agency, to try to win the arms technology race. The idea was "that we would not get surprised again," said Robert Taylor, the Arpa scientist who secured the money for the Arpanet, persuading the agency's head to give him a million dollars that had been earmarked for ballistic missile research. With another pioneer of the early internet, JCR Licklider, Taylor co-wrote the paper, "The Computer As A Communication Device", which hinted at what was to come. "In a few years, men will be able to communicate more effectively through a machine than face to face," they declared. "That is rather a startling thing to say, but it is our conclusion."

On the other hand, the breakthrough accomplished that night in 1969 was a decidedly down-to-earth one. The Arpanet was not, in itself, intended as some kind of secret weapon to put the Soviets in their place: it was simply a way to enable researchers to access computers remotely, because computers were still vast and expensive, and the scientists needed a way to share resources. (The notion that the network was designed so that it would survive a nuclear attack is an urban myth, though some of those involved sometimes used that argument to obtain funding.) The technical problem solved by the IMPs wasn't very exciting, either. It was already possible to link computers by telephone lines, but it was glacially slow, and every computer in the network had to be connected, by a dedicated line, to every other computer, which meant you couldn't connect more than a handful of machines without everything becoming monstrously complex and costly. The solution, called "packet switching" n which owed its existence to the work of a British physicist, Donald Davies n involved breaking data down into blocks that could be routed around any part of the network that happened to be free, before getting reassembled at the other end.

"I thought this was important, but I didn't really think it was as challenging as what I thought of as the 'real research'," says Crocker, a genial Californian, now 65, who went on to play a key role in the expansion of the internet. "I was particularly fascinated, in those days, by artificial intelligence, and by trying to understand how people think. I thought that was a much more substantial and respectable research topic than merely connecting up a few machines. That was certainly useful, but it wasn't art." Still, Kleinrock recalls a tangible sense of excitement that night as Kline sat down at the SDS Sigma 7 computer, connected to the IMP, and at the same time made telephone contact with his opposite number at Stanford. As his colleagues watched, he typed the letter L, to begin the word LOGIN.

"Have you got the L?" he asked, down the phone line. "Got the L," the voice at Stanford responded.
Kline typed an O. "Have you got the O?"

"Got the O," Stanford replied.

Kline typed a G, at which point the system crashed, and the connection was lost. The G didn't make it through, which meant that, quite by accident, the first message ever transmitted across the nascent internet turned out, after all, to be fittingly biblical:

"LO."

Frenzied visions of a global conscious brain

One of the most intriguing things about the growth of the internet is this: to a select group of technological thinkers, the surprise wasn't how quickly it spread across the world, remaking business, culture and politics but that it took so long to get off the ground. Even when computers were mainly run on punch-cards and paper tape, there were whispers that it was inevitable that they would one day work collectively, in a network, rather than individually. (Tracing the origins of online culture even further back is some people's idea of an entertaining game: there are those who will tell you that the Talmud, the book of Jewish law, contains a form of hypertext, the linking-and-clicking structure at the heart of the web.) In 1945, the American presidential science adviser, Vannevar Bush, was already imagining the "memex", a device in which "an individual stores all his books, records, and communications", which would be linked to each other by "a mesh of associative trails", like weblinks. Others had frenzied visions of the world's machines turning into a kind of conscious brain. And in 1946, an astonishingly complete vision of the future appeared in the magazine Astounding Science Fiction. In a story entitled A Logic Named Joe, the author Murray Leinster envisioned a world in which every home was equipped with a tabletop box that he called a "logic":

"You got a logic in your house. It looks like a vision receiver used to, only it's got keys instead of dials and you punch the keys for what you wanna get . . . you punch 'Sally Hancock's Phone' an' the screen blinks an' spatters an' you're hooked up with the logic in her house an' if somebody answers you got a vision-phone connection. But besides that, if you punch for the weather forecast (or) who was mistress of the White House durin' Garfield's administration . . . that comes on the screen too. The relays in the tank do it. The tank is a big buildin' full of all the facts in creation. . . hooked in with all the other tanks all over the country . . . The only thing it won't do is tell you exactly what your wife meant when she said, 'Oh, you think so, do you?' in that peculiar kind of voice".

Despite all these predictions, though, the arrival of the internet in the shape we know it today was never a matter of inevitability. It was a crucial idiosyncrasy of the Arpanet that its funding came from the American defence establishment but that the millions ended up on university campuses, with researchers who embraced an anti-establishment ethic, and who in many cases were committedly leftwing; one computer scientist took great pleasure in wearing an anti-Vietnam badge to a briefing at the Pentagon. Instead of smothering their research in the utmost secrecy n as you might expect of a cold war project aimed at winning a technological battle against Moscow n they made public every step of their thinking, in documents known as Requests For Comments.

Deliberately or not, they helped encourage a vibrant culture of hobbyists on the fringes of academia n students and rank amateurs who built their own electronic bulletin-board systems and eventually FidoNet, a network to connect them to each other. An argument can be made that these unofficial tinkering did as much to create the public internet as did the Arpanet. Well into the 90s, by the time the Arpanet had been replaced by NSFNet, a larger government-funded network, it was still the official position that only academic researchers, and those affiliated to them, were supposed to use the network. It was the hobbyists, making unofficial connections into the main system, who first opened the internet up to allcomers.

What made all of this possible, on a technical level, was simultaneously the dullest-sounding and most crucial development since Kleinrock's first message. This was the software known as TCP/IP, which made it possible for networks to connect to other networks, creating a "network of networks", capable of expanding virtually infinitely n which is another way of defining what the internet is. It's for this reason that the inventors of TCP/IP, Vint Cerf and Bob Kahn, are contenders for the title of fathers of the internet, although Kleinrock, understandably, disagrees. "Let me use an analogy," he says. "You would certainly not credit the birth of aviation to the invention of the jet engine. The Wright Brothers launched aviation. Jet engines greatly improved things."

The spread of the internet across the Atlantic, through academia and eventually to the public, is a tale too intricate to recount here, though it bears mentioning that British Telecom and the British government didn't really want the internet at all: along with other European governments, they were in favour of a different networking technology, Open Systems Interconnect. Nevertheless, by July 1992, an Essex-born businessman named Cliff Stanford had opened Demon Internet, Britain's first commercial internet service provider. Officially, the public still wasn't meant to be connecting to the internet. "But it was never a real problem," Stanford says today. "The people trying to enforce that weren't working very hard to make it happen, and the people working to do the opposite were working much harder." The French consulate in London was an early customer, paying Demon £10 a month instead of thousands of pounds to lease a private line to Paris from BT.

After a year or so, Demon had between 2,000 and 3,000 users, but they weren't always clear why they had signed up: it was as if they had sensed the direction of the future, in some inchoate fashion, but hadn't thought things through any further than that. "The question we always got was: 'OK, I'm connected n what do I do now?'" Stanford recalls. "It was one of the most common questions on our support line. We would answer with 'Well, what do you want to do? Do you want to send an email?" 'Well, I don't know anyone with an email address.' People got connected, but they didn't know what was meant to happen next."

Fortunately, a couple of years previously, a British scientist based at Cern, the physics laboratory outside Geneva, had begun to answer that question, and by 1993 his answer was beginning to be known to the general public. What happened next was the web

The birth of the web

I sent my first email in 1994, not long after arriving at university, from a small, under-ventilated computer room that smelt strongly of sweat. Email had been in existence for decades by then n the @ symbol was introduced in 1971, and the first message, according to the programmer who sent it, Ray Tomlinson, was "something like QWERTYUIOP. (The test messages, Tomlinson has said, "were entirely forgettable, and I have, therefore, forgotten them."). But according to an unscientific poll of friends, family and colleagues, 1994 seems fairly typical: I was neither an early adopter nor a late one. A couple of years later I got my first mobile phone, which came with two batteries: a very large one, for normal use, and an extremely large one, for those occasions on which you might actually want a few hours of power. By the time I arrived at the Guardian, email was in use, but only as an add-on to the internal messaging system, operated via chunky beige terminals with green-on-black screens. It took for ever to find the @ symbol on the keyboard, and I don't remember anything like an inbox, a sent-mail folder, or attachments. I am 14 years old, but sometimes I feel like Methuselah.

I have no recollection of when I first used the world wide web, though it was almost certainly when people still called it the world wide web, or even W3, perhaps in the same breath as the phrase "information superhighway", made popular by Al Gore. (Or "infohaban": did any of us really, ever, call the internet the "infohaban"?) For most of us, though, the web is in effect synonymous with the internet, even if we grasp that in technical terms that's inaccurate: the web is simply a system that sits on top of the internet, making it greatly easier to navigate the information there, and to use it as a medium of sharing and communication. But the distinction rarely seems relevant in everyday life now, which is why its inventor, Tim Berners-Lee, has his own legitimate claim to be the progenitor of the internet as we know it. The first ever website was his own, at CERN: info.cern.ch.
arguing that it is a vastly superior alternative to the web. "WE FIGHT ON," the Xanadu website declares, sounding rather beleaguered, not least since the declaration is made on a website.

Web browsers crossed the border into mainstream use far more rapidly than had been the case with the internet itself: Mosaic launched in 1993 and Netscape followed soon after, though it was an embarrassingly long time before Microsoft realised the commercial necessity of getting involved at all. Amazon and eBay were online by 1995. And in 1998 came Google, offering a powerful new way to search the proliferating mass of information on the web. Until not too long before Google, it had been common for search or directory websites to boast about how much of the web's information they had indexed n the relic of a brief period, hilarious in hindsight, when a user might genuinely have hoped to check all the webpages that mentioned a given subject. Google, and others, saw that the key to the web's future would be helping users exclude almost everything on any given topic, restricting search results to the most relevant pages.

Without most of us quite noticing when it happened, the web went from being a strange new curiosity to a background condition of everyday life: I have no memory of there being an intermediate stage, when, say, half the information I needed on a particular topic could be found online, while the other half still required visits to libraries. "I remember the first time I saw a web address on the side of a truck, and I thought, huh, OK, something's happening here," says Spike Ilaqua, who years beforehand had helped found The World, the first commercial internet service provider in the US. Finally, he stopped telling acquaintances that he worked in "computers", and started to say that he worked on "the internet", and nobody thought that was strange.

It is absurd n though also unavoidable here n to compact the whole of what happened from then onwards into a few sentences: the dotcom boom, the historically unprecedented dotcom bust, the growing "digital divide", and then the hugely significant flourishing, over the last seven years, of what became known as Web 2.0. It is only this latter period that has revealed the true capacity of the web for "generativity", for the publishing of blogs by anyone who could type, for podcasting and video-sharing, for the undermining of totalitarian regimes, for the use of sites such as Twitter and Facebook to create (and ruin) friendships, spread fashions and rumours, or organise political resistance. But you almost certainly know all this: it's part of what these days, in many parts of the world, we call "just being alive".

The most confounding thing of all is that in a few years' time, all this stupendous change will probably seem like not very much change at all. As Crocker points out, when you're dealing with exponential growth, the distance from A to B looks huge until you get to point C, whereupon the distance between A and B looks like almost nothing; when you get to point D, the distance between B and C looks similarly tiny. One day, presumably, everything that has happened in the last 40 years will look like early throat-clearings o mere preparations for whatever the internet is destined to become. We will be the equivalents of the late-60s computer engineers, in their horn-rimmed glasses, brown suits, and brown ties, strange, period-costume characters populating some dimly remembered past.

Will you remember when the web was something you accessed primarily via a computer? Will you remember when there were places you couldn't get a wireless connection? Will you remember when "being on the web" was still a distinct concept, something that described only a part of your life, instead of permeating all of it? Will you remember Google?
Click on the link below. Examine the website and answer the questions for “Source 3.”

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