# Restricted Access: How the Internet Can Be Used to Promote Reading and Learning

Laura Derksen, Catherine Michaud-Leclerc and Pedro CL Souza*

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**Abstract**

Can schools use the internet to promote reading and learning? We provided Wikipedia access to randomly-selected students in Malawian boarding secondary schools. Students used the online resource broadly and intensively, and found it trustworthy, including for information about news and safe sex. We find a $0.10\sigma$ impact on English exam scores, and a higher impact among low achievers ($0.20\sigma$). Students used Wikipedia to study Biology, and exam scores increased for low achievers ($0.14\sigma$). Our results show that by restricting internet access to a source of engaging and accessible reading material, it is possible to encourage independent reading and affect educational outcomes.

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*Derksen: University of Toronto (corresponding author, email: laura.derksen@utoronto.ca); Michaud-Leclerc: Laval University (email: catherine.michaud-leclerc.1@ulaval.ca); Souza: Queen Mary University (email: p.souza@qmul.ac.uk). We thank the editor, Karen Macours, and three anonymous referees at the Journal of Development Economics for their constructive and thoughtful feedback. We thank Natalie Bau, Gustavo Bobonis, Jonas Hjort, Clément Imbert, Jason Kerwin, Anita McGahan, Uros Petronijevic, Steve Pischke, Roland Rathelot, Abhijeet Singh, seminar participants at Columbia, Notre Dame, PUC-Rio, UMN, SFU, the University of Toronto, AFE, CEA and MWIEDC for excellent comments. Fatema Bhayani, Tarun Chopra, Jessica Gallant, Dina O'Brien, Leandro Pongeluppe, Ethan Sansom, and Tanvi Shetty provided outstanding research assistance. We thank Abdallah Chilungo and the field team for their dedication. Errors and omissions remain our own. This study was approved by the University of Toronto Research Ethics Board and the Malawi National Committee on Research Ethics in the Social Sciences and Humanities (P08/17/204). The study was funded by a SSHRC Insight Development grant, and pre-registered in the American Economic Association RCT Registry, number AEARCTR-0003824. This paper was previously circulated with the title "Searching for Answers: The Impact of Student Access to Wikipedia".

# 1 Introduction

In the developing world, school books are often in short supply, yet programs that simply provide reading material often have no impact on literacy or academic performance.[1] If reading material is not at the right level or does not cater to student interests, students are unlikely to read it or learn from it. Effective reading interventions usually require teacher training and engagement.[2] In order to be compelling, useful and accessible on its own, reading material must satisfy the demands of heterogeneous students, and be relevant across contexts.

As the internet expands worldwide, information technology offers a potential solution. The internet hosts reading material on almost every topic, at every level of difficulty. Young people in particular are enthusiastic internet users; in Africa, young people aged 15 to 24 use the internet at twice the rate of the general population.[3] Yet, internet in schools presents challenges of its own. While information on the internet is plentiful, it varies in its accuracy, trustworthiness and complexity (MacMillan and MacKenzie, 2012; Allcott and Gentzkow, 2017; Lazer et al., 2018). Moreover, students often prefer games, videos and social media to learning. In fact there is evidence that full internet access does not improve academic performance.[4]

In this paper, we show that the internet has a place in schools, and can be introduced in a way that promotes reading and learning. We provide students with an online experience restricted to Wikipedia, a vast yet accessible open source of accurate read-

[1] See for example Glewwe, Kremer and Moulin (2009), Borkum, He and Linden (2012), Sabarwal, Evans and Marshak (2014), and Knauer et al. (2020).

[2] Examples include He, Linden and MacLeod (2008), Machin and McNally (2008), Abeberese, Kumler and Linden (2014), Lucas et al. (2014), Bai et al. (2016) Piper et al. (2018), Brunette et al. (2019), Kerwin and Thornton (2021).

[3] Source: International Telecommunications Unit `https://www.itu.int/en/ITU-D/Statistics/Pages/stat/`, accessed on May 13, 2019.

[4] See Goolsbee and Guryan (2006), Vigdor, Ladd and Martinez (2014), Faber, Sanchis-Guarner and Weinhardt (2015), and Malamud et al. (2019).

ing material.[5,6] This preserves one of the most exciting aspects of the internet: detailed and up-to-date information on almost any topic. Restricted access to online information might compel students to spend time reading, while avoiding other online distractions that do not involve reading. Wikipedia is simple to use and understand, even for students of heterogeneous ability. Many articles have versions written in both standard and simple English. While restricted, this intervention still allows students to easily search for information they need online, and click to learn more about concepts they do not understand, including concepts related to their studies. In this sense, the internet allows students to effectively customize the contents of their learning as well as the difficulty level.

We provide Malawian secondary school students with access to online information, restricted to Wikipedia, and use novel data on student browsing behavior, as well as survey and administrative data, to answer three research questions. First, how do students use this new online resource? Do they find it engaging and accessible? Second, this intervention gives students access to reading material on a vast range of topics. Are students compelled to spend time reading, and how does this affect English language ability? Third, what is the impact on academic performance in Biology, an important subject for which study materials are crucial? Biology is the most popular subject, and is important for career aspirations, as many secondary students in Malawi go on to a career in healthcare.[7]

We conducted a randomized experiment in government boarding schools in Malawi,

[5]Rather than restricting to a single information source, existing work measured the impact of full scale internet access on education (Bulman and Fairlie, 2016; Malamud, 2019; Yanguas, 2020), political and economic behavior (Bailard, 2012; Miner, 2015; Campante, Durante and Sobbrio, 2018; Chen and Yang, 2019) and development (Galperin and Viecens, 2017; Hjort and Poulsen, 2019). Randomized experiments specifically involving Wikipedia focused primarily on the decision to contribute to a public good (Hinnosaar, 2019; Chen et al., 2020).

[6]There is evidence that Wikipedia is mostly accurate, though incomplete. See Giles (2005), Rosenzweig (2006), Heilman et al. (2011), and Mesgari et al. (2015).

[7]We pre-registered final (term 3) English and Biology scores as our two primary outcomes (AEA RCT Registry number AEARCTR-0003824). English and Biology are core courses and are most often named as a favorite subject at baseline, and these subjects have the highest rate of exam completion. English is an official language of Malawi, and most courses are taught in English.

a country with rapidly improving internet infrastructure, but where students have limited internet experience and no internet access at school. This setting allows us to isolate both treatment and control students from the broader internet. Students were allowed to use Wikipedia inside a classroom referred to as a digital library, using anonymous usernames. Students were aware that their browsing behavior was private, and that browsing histories could not be linked to individual students. The digital library was open evenings and weekends during one school year, and access was restricted to treated students. This design limits potential spillovers on English language skills and Biology exam scores. Students did not have any other internet access during term time.

The design of this study took into account several ethical considerations. First, Wikipedia contains information on topics that some educators might view as inappropriate. We discussed the breadth of information provided with administrators, who were supportive.[8] Second, schools and workplaces often monitor internet browsing behavior. Because browsing was restricted only to Wikipedia, we rather decided to protect privacy by anonymizing browser histories. Finally, the randomization may have been seen by students as unfair. From our perspective, randomization was justified by the fact that, at the outset, we were uncertain whether the intervention would support or undermine student learning.

Students found the online material engaging, as evidenced by their frequent and broad use of Wikipedia. They spent, on average, one hour and twenty minutes per week online. Rather than relying on aggregate usage statistics, we observe individual browsing histories, which allows us to characterize demand for specific topics at the level of an individual. Each student browsed, on average, more than 800 different pages across a range of topics.

Students came to use and trust Wikipedia, particularly for topics which are important, prone to misinformation and often absent from school books, such as world news

[8]In particular, access to broad and accurate information on sex and sexuality is mentioned explicitly the Malawian secondary school syllabus.

and safe sex. We find spikes in activity in the week surrounding world news events that occurred during the experiment. We also show that students with access to Wikipedia are able to find news information that control group students cannot. Young people are generally curious about sex, and we find that students spent 7 percent of their browsing time on topics related to sex and sexuality. While Wikipedia pages are informative, and access to accurate information about sex can be important (Dupas, 2011; Kerwin, 2018; Derksen, Muula and van Oosterhout, 2021), students may have browsed these pages not only for information but also as a form of entertainment. One third of the time spent browsing these topics overlapped with topics from the school syllabus, such as pregnancy and reproductive health. Students sought information on both news and sex and sexuality independently, without prompts or incentives.[9]

Students used the internet-enabled devices intensively for general interest reading, and we find a positive impact on English final exam scores. We find a significant improvement on average ($0.10\sigma$) and for low achievers in particular ($0.20\sigma$).[10] We do not find any impact on high achievers. Students in the treatment group spent more than one hour per week reading articles in English, primarily on topics that were not directly related to the school syllabus. This should not be viewed as a harmful distraction, as we can rule out even small negative effects across most subjects. In fact, we find a positive treatment effect on English exam scores for low achievers. This heterogeneity does not appear to be driven by differences in usage. On average, low and high achievers are similarly able to find information online, and low achievers in fact spend slightly fewer hours in the digital library. We conclude that an additional hour spent reading must have a greater impact for low achievers than for high achievers, perhaps because high achievers are already proficient in English at baseline.

[9] In fact, Chen and Yang (2019) show that even when provided with an internet VPN, university students in China do not search for international news unless incentivized. Our results suggest that interest in world news may be different outside of a censored regime.

[10] Here, we define a low achiever to be a student whose average exam score (English and Biology) at baseline is below the median.

By linking search terms to the school syllabus, we show that students find Wikipedia to be a useful study resource, especially for Biology. In other contexts, survey data suggests that students see value in Wikipedia as a study tool (Lim, 2009; Head and Eisenberg, 2010). Here we observe student browsing choices directly. We did not incentivize or pressure students to use the internet for school, yet the average student did spend 22 percent of their time on pages related to the school syllabus. They spent more than twice as much time on Biology-related pages as on any other school subject.

This translates to an improvement in study time productivity and Biology exam scores for low achievers. We find a positive but insignificant impact on Biology exam scores ($0.06\sigma$), and a significant impact for low achievers ($0.14\sigma$). We again find no impact on high achievers. Low achievers did not spend more time on syllabus-related pages than high achievers, and neither low nor high achievers changed their total study time in response to the intervention. This implies an increase in study time productivity for low achievers. Indeed, we find that most treatment students, and especially low achievers, preferred Wikipedia to their Biology textbooks and teachers, and were able to find academic information that their control group peers could not. The fact that information on Wikipedia is particularly easy to find and understand could explain larger gains for students who were struggling at baseline. We do not find any treatment effect on student education or career goals, which suggests that the effect on Biology exam scores is driven by study inputs and not by a change in aspirations.

This paper shows that by providing suitably restricted internet access, it is possible to engage students in independent reading, and improve academic outcomes. The fact that access to Wikipedia can impact exam scores is remarkable, because interventions that provide full internet access are usually ineffective (Goolsbee and Guryan, 2006; Vigdor, Ladd and Martinez, 2014; Faber, Sanchis-Guarner and Weinhardt, 2015; Malamud et al., 2019), unless it is integrated formally into the classroom (Kho, Lakdawala and Naka-

sone, 2020).[11] The internet provides students with a compelling and ever expanding set of reading material, but Malamud et al. (2019) find that students primarily use the unrestricted internet for videos, social media, and games.[12] One possible solution is to restrict resources to reading material. Yet, interventions that provide books to schools are also typically ineffective (Glewwe, Kremer and Moulin, 2009; Borkum, He and Linden, 2012; Sabarwal, Evans and Marshak, 2014). This highlights the importance of not only supplying reading materials, but finding a way to encourage students to use them (Falisse, Huysentruyt and Olofsgård, 2019). There is a vast literature in the theory of education that emphasizes the importance of stimulating self-led, inquiry-based learning; students are more likely to engage with material they find interesting and relevant.[13] In this paper, we demonstrate the empirical importance of this type of student engagement. By providing access to a wide-ranging and up-to-date source of online reading material, it is possible to engage student interest without teacher involvement or incentives.

Second, we contribute to an expanding literature on interventions that can close the achievement gap, especially involving computer programs that "teach at the right level." Such programs have shown promise, particularly for low achievers (Banerjee et al., 2007; Linden, 2008; Barrow, Markman and Rouse, 2009; Muralidharan, Singh and Ganimian, 2019; Beg et al., Forthcoming). Muralidharan, Singh and Ganimian (2019) highlight a potential mechanism: even in heterogeneous classrooms, a computer program can adapt to a student's ability. However, these programs are context specific, rely on proprietary software, and often involve teachers and administrators.[14] Wikipedia offers a free, open

[11] Providing computers is also typically ineffective (Malamud and Pop-Eleches, 2011; Fairlie and Robinson, 2013; Beuermann et al., 2015; Cristia et al., 2017), though some programs (which include educational software) find improvements in computer skills and math (Carrillo, Onofa and Ponce, 2011; Mo et al., 2013). See Bulman and Fairlie (2016) for a broad review of the literature on information technology and education, and Rodriguez-Segura (2021) for a review of educational technology in developing countries.

[12] Parents may attempt to limit internet access for this reason, rather than install appropriate parental controls (Gallego, Malamud and Pop-Eleches, 2020).

[13] Dewey (1938), Bruner (1961), Freire (1970), and Rancière (1991) have promoted self-led and inquiry-based learning as a pedagogical method in which teachers guide students to learn independently. More recently, this topic has been studied by Biesta (2007), hooks (2010), McLaren (2015), and Giroux (2020).

[14] Remedial lessons (without computers) also improve scores for low achievers (Banerjee et al., 2007).

source alternative to this tailored approach which is still appropriate for students of heterogeneous ability. It allows each student to search for the specific information they need, written in accessible language. Some other self-led reading interventions have also been shown to disproportionately impact low achievers, as they allow students to set their own level and pace (Falisse, Huysentruyt and Olofsgård, 2019). On the other hand, if materials are too advanced for some students, they might in fact widen the achievement gap (Glewwe, Kremer and Moulin, 2009). Baseline literacy is key; in secondary school, even low achievers are proficient enough to engage with new material, while high achievers may be too proficient to improve further.

Finally, this paper contributes to an emerging literature on education interventions in secondary school. Most education interventions to date target primary or middle school students,[15] and learning gaps in secondary school merit attention. While secondary school attendance is rising, completion rates are low in Malawi and across sub-Saharan Africa.[16] Yet, returns to secondary school are high (Ozier, 2018). Secondary school is a necessary step towards postsecondary education, and a career in policy, education or healthcare. Finally, the effect of providing study material to secondary schools is likely to be different from the effect observed in primary schools, due to the advanced subject matter, and the fact that students are not illiterate. In this paper we show that reading material can in fact be useful to secondary students with a base level of literacy, for an advanced subject such as Biology.

The internet can serve as a useful substitute for English books and Biology textbooks, and is an accessible, cost-effective and up-to-date alternative for schools operating in low

[15]See Banerjee et al. (2013) for a review of studies which focus on post-primary school students. Furthermore, Evans and Mendez Acosta (2020) review recent empirical education research in Africa, and find that one quarter of articles discuss secondary education. The majority of these articles focus on girls specifically or the impact of cash transfers or subsidies. Barrera-Osorio and Linden (2009) study an ICT intervention which did include secondary schools.

[16]In Malawi, 26 percent of women and 36 percent of men have at least some secondary education, however, less than half of those who start go on to graduate, see Malawi DHS 2015-16 (National Statistical Office (Malawi) and ICF, 2017). According to Barro and Lee (2013), in 2010, 27 percent of individuals in sub-Saharan Africa aged 15 and over had completed some secondary education.

resource settings.[17] Books are expensive to ship, necessarily limited in scope, and become out of date. Internet-enabled tablets and phones are available locally, and internet infrastructure is in place. We estimate that our intervention, as implemented, costs $4 USD per student per month. Internet and technology costs are decreasing over time, and if implemented in entire schools, the intervention might benefit from additional economies of scale. This is clearly more cost-effective than programs that provide reading material to primary schools to promote reading, with no impact. It is also more cost-effective than many computer-aided learning programs. It is, however, less cost-effective than some of the most impactful primary school interventions, especially those that improve the quality of instruction. It is difficult to compare our intervention to other potential impacts in secondary school, as evidence is limited (Banerjee et al., 2013), but we might expect smaller returns in secondary school due to higher baseline ability levels.

The paper proceeds as follows. Section 2 describes the setting, the experimental design, the intervention, and our data sources. In Section 3, we explore student use of Wikipedia and the digital library. In Section 4, we investigate whether students were able to use the digital library to find information. Section 5 presents our results on student academic performance. We conclude in Section 6 by discussing mechanisms, policy implications and external validity.

# 2 The Intervention: Restricted Internet in Schools

## 2.1 Wikipedia

Wikipedia is an online encyclopedia, providing up-to-date reading material on a wide range of topics. It is the largest and most visited reference site on the internet. It

[17] Bando et al. (2017) show that digital content can be used as a cost-effective substitute for primary school textbooks.

is a source of collaborative, accurate, open source information.[18] Content is created through open collaboration, and its accuracy on scientific topics is comparable to an offline encyclopedia (Giles, 2005). However, Wikipedia is frequently updated, and offers far more informational content than an offline encyclopedia, in terms of breadth, depth, and relevance.

Wikipedia is a high quality resource for secondary school, and is accessible to students of heterogeneous ability. Information is easy to find and understand, and it is easy for students to search directly for concepts they find difficult. Articles exist in English and Simple English[19] (among many other languages), and Wiktionary serves as a companion dictionary. Wikipedia has a page for every topic on the typical secondary school syllabus, and often provides more detail than a textbook. For example, the English page for photosynthesis (a topic from secondary school Biology) has over 7000 words and several diagrams, and students can easily click links to similarly detailed pages on related concepts. There is also a Wikipedia page for photosynthesis in Simple English, with less detail, but with simple explanations, such as "Photosynthesis is the process by which plants and other things make food."

## 2.2 Setting and Sample

Malawi is a country in southern Africa with a GDP of less than $400 USD per capita, yet internet infrastructure is present throughout the country.[20] In 2006, 93 percent of the Malawian population lived in an area with access to a mobile network.[21] This surpasses the network coverage in neighboring Zambia and Mozambique (both at around

[18]Source: Wikipedia, https://en.wikipedia.org/wiki/Wikipedia, accessed on May 23rd 2019. Wikipedia is free and owned by Wikimedia, a non-profit organization with no advertising.

[19]Simple English is a language defined by Wikipedia, which uses simpler words and shorter sentences than English Wikipedia. As of 2019, Simple English Wikipedia has more than 150,000 pages.

[20]According to the World Bank, GDP per capita in 2017 was $339 USD. This is well below the Sub-Saharan Africa and world average of $1,575 and $10,749, respectively. Current USD values.

[21]See Buys et al. (2009). 2G networks are largely accessible in rural areas, and 3G and 4G networks are available in towns and cities. Data networks are reliable even during electricity outages. See Batzilis et al. (2010) for a detailed description and analysis of the mobile network in Malawi.

40 percent), and is comparable to the much richer South Africa (see Table A1).

Though internet infrastructure exists, access to the internet is unaffordable for most Malawians. 54 percent of Malawian households have a mobile phone (DHS, 2015-16),[22] but most of these phones do not have internet capabilities. Moreover, 1GB of internet costs the average Malawian 18 percent of their monthly income (see Table A1). This income share is larger than in Mozambique or Zambia, where incomes are higher. However, prices are dropping rapidly, and internet use in Malawi is on the rise. In 2007, less than 1 percent of Malawians had regular internet access (see Table A1). In 2015, this rose to approximately 12 percent (DHS, 2015-16).

Malawi is on the verge of internet adoption, yet Malawian schools do not have internet access, making this a unique and appropriate setting for our study. The presence of internet infrastructure makes internet in schools feasible. Yet, most of the population, including youth, have limited internet experience. At school, mobile phones are usually prohibited. While some schools do have computer labs, they are typically offline.

At the same time, secondary school is challenging and completion is rare. Only 10 percent of women and 17 percent of men complete secondary school (DHS, 2015-16). Courses are taught in English, and require adequate language skills. The courses are difficult, and study materials are likely to be important.[23] In the fourth and final year, students take a national examination which determines university admission. Among those who sit their final exams, more than one third fail.[24]

Our experiment took place in four government boarding schools which serve students of mixed socioeconomic status. Each school has approximately five hundred students spread over four forms (grade levels). Government boarding schools are common in Malawi and across sub-Saharan Africa. They are more academically competitive than

[22] See National Statistical Office (Malawi) and ICF (2017) for Malawi DHS, 2015-16.

[23] The core subjects are English, Biology, Chichewa (the local language) and Mathematics. Other subjects including Chemistry, Geography, History, Life Skills, Physics, and Social Studies are offered depending on the school, form (grade level) and interests.

[24] The 2018 pass rate for the Malawi Secondary Certificate of Education (MSCE) was 63 percent (https://maneb.edu.mw).

government day schools and most private schools (de Hoop, 2010). However, even in these schools, many students do struggle academically. In particular, one quarter of students had an English exam score below 50/100 in the year before the intervention. While government boarding schools attract good students, fees are not exorbitant.[25] Indeed, according to our baseline survey, many students at our sample schools are of lower socioeconomic status: 42 percent do not have electricity at home, and 45 percent do not have running water. One third of students have at least one parent who did not complete primary school.

Boarding schools provide a controlled environment; students have no access to the internet outside of our intervention, allowing us to cleanly limit internet use to Wikipedia. At the time of the intervention, the school grounds had consistent 3G or 4G network coverage. However, students were not allowed to access the internet or use phones, even outside of class time, and being caught with a phone at school was grounds for suspension. Students sleep in dormitories, and are not permitted to leave the school grounds. In particular, they do not go home during the term, so those who do have home internet access cannot use it.[26]

## 2.3 Experimental Design

In each boarding school, we set up a digital library where students could access the restricted internet outside of class time. The digital library was open most of one school year: from November 2017 to June 2018. It was open for four hours after school and eight hours on Saturday and Sunday. Each digital library was equipped with 12 internet-enabled Android devices. These devices were battery powered, and the internet was typically accessible even during power outages. The devices were shared among 69 to 82 students in each school. We used password-protected software to restrict the devices

[25] Admission is based on a national primary school exam. The school fees in our schools range from 75 to 165 USD per term, with many students on bursaries or scholarships.

[26] Students are sent home for two to four weeks between terms.

to Wikipedia and Wiktionary.[27] We put links to English Wikipedia, Simple English Wikipedia and Wiktionary on the main login page.

Inside the digital library, students could browse online information privately and anonymously. The digital library was supervised by our research staff, referred to as digital librarians. To log into a device, each student used a personal, unique and anonymous username and password.[28] The librarian did not monitor the content browsed by students. Students used the devices on their own (not in pairs or groups), and were not permitted to leave the digital library with a device. Students were allowed to take notes, and many did, but students were not allowed to study in the digital library unless they were actively using a device.

In October, 2017, we introduced the project to students, conducted a baseline survey, and collected baseline exam scores.[29] Our team of eight enumerators surveyed every student in Forms 2, 3 and 4. In total, we interviewed 1,508 students to collect information on their background, past internet use, time use, career and life aspirations, interests, and social networks.

After completing the baseline survey, we randomly assigned students to a treatment group or to a larger control group. The randomization assigned one fifth of students, a total of 301, to the treatment group. The remaining 1,207 students formed the control group. A sparse treatment ratio was chosen to limit spillovers, and jealousy, between students. We also hoped this might reduce feelings of unfairness or disappointment, as a large majority of students found themselves in the control group. At endline, 79 percent of control students and 91 percent of treatment students felt the program was fair (see Appendix Table A2).[30] This also limits the potential for teachers to adapt their

[27] We used the software *Kioware* to prevent students from accessing other webpages or applications. Students did not manage to exit the software or access other applications on the devices.

[28] No one, including the research team, would be able to link a specific student to their browsing history.

[29] We introduced the project to students and teachers at each school, one form at a time, and all received the same information. See the supplementary materials for a detailed description of the classroom introduction.

[30] In Section 6, we explore whether this difference can explain the treatment effects we find.

lesson plans in tandem, as most of their students do not have access to the internet. A subset of students in the control group (299 students out of 1,207) was randomly assigned to a supplementary survey sample. This subsample would be surveyed more extensively for the construction of some secondary outcomes.

We randomized at the student level, and stratified on four key variables: school, form, exam scores and internet experience.[31] The bin for exam scores is defined as above or below the median score (within the school and form). We used the average of English and Biology exam scores. These are our two primary outcomes; we have data for both English and Biology scores for 95 percent of students at baseline. We constructed a separate bin for students with missing exam score data. Internet experience is defined as whether the student has ever used the internet. There are 51 stratification bins. Panel A of Table 1 shows that our randomization is balanced across baseline variables (Appendix Table A3 shows balance across stratification variables).

After the randomization took place, we publicly announced the names of the students in the treatment group, and held a mandatory induction session in the digital library.[32] During the induction, the students obtained an anonymous username which would be linked to their browsing history. The first letter of the username identifies coarsened student characteristics. Students with similar characteristics attended the same induction, and drew their usernames from the same envelope. This made it clear that browsing data obtained by the researchers could not be linked to a particular student. While ensuring privacy, this does prevent us from linking detailed browsing patterns to other outcomes at the individual level.

[31] We used a computer to randomize using the Stata command *randtreat*, seeded with the date of the randomization (2910).

[32] The digital librarians explained the digital library and its rules. They also showed students how to access Wikipedia, and allowed the students to practice for fifteen minutes. Students were told that breaking the rules would result in suspension or removal of access. See the supplementary materials for a detailed description of the induction and digital library rules.

Table 1: Balance Table and Attrition in Endline Surveys and Exam Scores

| | (1) Treatment | (2) Control (subsample) | (3) *p*-value | (4) Control (full) | (5) *p*-value |
|---|---|---|---|---|---|
| Panel A. Balance, non-stratification variables | | | | | |
| Average exam score in English | 57.188 | 57.626 | .694 | 57.429 | .780 |
| | (13.187) | (13.533) | | (13.005) | |
| Average exam score in Biology | 53.810 | 53.267 | .709 | 53.544 | .816 |
| | (17.196) | (17.640) | | (17.985) | |
| Average exam score in Science | 55.300 | 54.233 | .498 | 54.041 | .303 |
| | (18.317) | (19.498) | | (19.559) | |
| Average exam score in Humanities | 58.778 | 57.998 | .520 | 58.369 | .676 |
| | (14.964) | (14.128) | | (14.582) | |
| Average exam score in Math | 44.892 | 43.535 | .476 | 43.899 | .501 |
| | (21.904) | (23.077) | | (22.622) | |
| Average exam score in Chichewa | 61.791 | 61.712 | .947 | 62.007 | .819 |
| | (14.438) | (13.782) | | (13.942) | |
| Age | 15.973 | 16.060 | .577 | 16.033 | .635 |
| | (1.971) | (1.845) | | (1.869) | |
| Female | .452 | .433 | .641 | .423 | .361 |
| | (.499) | (.496) | | (.494) | |
| District of origin | .605 | .574 | .444 | .575 | .348 |
| | (.490) | (.495) | | (.495) | |
| Mother's education | .746 | .698 | .224 | .718 | .258 |
| | (.436) | (.460) | | (.450) | |
| Father's education | .849 | .852 | .918 | .856 | .775 |
| | (.359) | (.356) | | (.351) | |
| Household has electricity | .611 | .557 | .179 | .576 | .262 |
| | (.488) | (.498) | | (.494) | |
| Household has mobile phone | .870 | .849 | .451 | .866 | .852 |
| | (.336) | (.359) | | (.340) | |
| Panel B. Attrition | | | | | |
| Endline A | .047 | .050 | .653 | .076 | .027 |
| | (.211) | (.219) | | (.265) | |
| Endline B | .083 | .084 | .933 | — | — |
| | (.276) | (.278) | | | |
| Exam scores (English) | .060 | .050 | .680 | .065 | .736 |
| | (.238) | (.219) | | (.246) | |
| Exam scores (Biology) | .063 | .054 | .700 | .069 | .715 |
| | (.244) | (.226) | | (.253) | |
| Number of students | 301 | 298 | | 1,207 | |

*Notes:* Panel A: Balance table across the treatment (N=301), subsample of control (N=298) and full sample of control (N=1,207) groups. (3) and (5) show the *p*-value of the difference between treatment and subsample of control, and treatment and full sample of control groups, respectively. District of origin equals 1 if the district where the student is from is the same district as the school district. Mother's and father's education is equal to one if she or he has completed primary education. Standard errors in parenthesis. Panel B: Differential attrition between treatment and control groups. Regression of attrition indicator in endline surveys A, B, and Biology and English scores on the treatment status with strata fixed effects

Treatment students were invited to visit the digital library during opening hours, and sign in with the digital librarian to use a device within the digital library. If all devices were in use, they would join the waitlist or come back later. If there were students waiting, usage was restricted to approximately 30 minutes. Only students in the treatment group used the digital library, and the librarians used student photos to verify identities.[33] This restriction limits the scope for any spillovers to the control group that would rely on direct access to devices, Wikipedia or the internet. Teachers did not have access to the devices.

# 3 How Students Used Wikipedia

In this section, we describe in detail how students in the treatment group used Wikipedia. Our browsing data is rich and granular, which allows us to provide a detailed analysis of browsing behavior, beyond a description of basic usage statistics. We explore how students use a new online information source, what types of information they value, and the tradeoff they face between general interests and academic subjects. Browsing behavior gives us a window into student interests and demand for information, which we will explore further in Section 4 using survey data. Understanding browsing behavior will also be key to interpreting results on academic performance in Section 5.

## 3.1 Browsing Data

Browsing data was recorded by software on our Wikipedia devices, and contains the complete sequence of pages visited by a particular student (linked to an anonymous username), a timestamp, and the time spent on each page. Although the browsing data

[33] Every week, a field team leader would visit each digital library to spot check the identities of the students and verify that no student in the control group was given access to the digital library. We also conducted spot checks, comparing student signatures to the baseline survey. We did not encounter a case where a control student gained access to the digital library.

does not identify any individual student, each username is linked to coarsened student characteristics.

Most students made frequent use of the digital library, and every student in the treatment group visited at least once. The average student visited the digital library on 33 days during the school year and each visit lasted 52 minutes.[34] This is approximately one hour and twenty minutes per week for each student, or 29 hours over the course of the year. Each student visited an average of 878 unique pages, and spent about two and a half minutes per page. 99.9 percent of pages visited were in English, and nearly 7 percent were in Simple English.

In Panel A of Figure 1 we present the distribution of browsing hours across students. The distribution is skewed to the right. While the average student spent 29 hours in the digital library, some students spent more than 150 hours browsing Wikipedia, over more than 100 visits. The time spent in the digital library is similarly distributed across low and high achievers (Panel B of Figure 1). This suggests that the intervention was accessible even to students with weaker language skills.

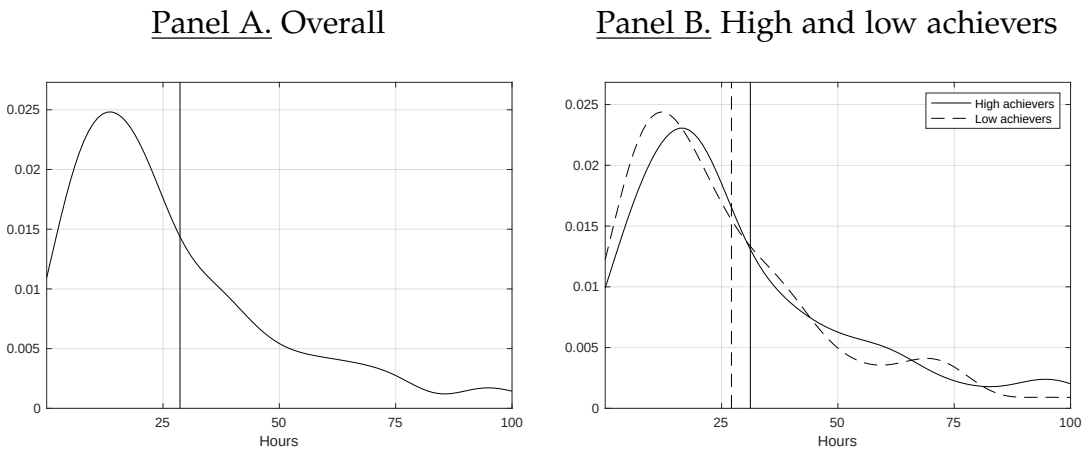
## 3.2 Topic Classifications

We use the Wikipedia category tree to classify pages according to broad topics in order to shed light on student interests and search behavior. Wikipedia has a user-generated and user-maintained category tree. The tree has 39 top-level categories which we adopt as topic classifications. Each top-level category branches into one or more subcategories which, in turn, may contain both pages and narrower subcategories. We trace each page visited by a student to one top-level category.[35]

[34]The digital library was open for 20-22 weeks, from November 2017 to June 2018, excluding Christmas and Easter vacations. We consider any browsing time within the same day to constitute one visit. Appendix Figure A1 shows browsing over time.

[35]The full list of top-level categories can be found at https://en.wikipedia.org/wiki/Category:Main_topic_classifications. For more information on the tree structure, see https://en.wikipedia.org/wiki/Wikipedia:Categorization#Topic_categories. A Wikipedia page typically belongs to more

Figure 1: Histogram of Hours Spent Browsing Wikipedia

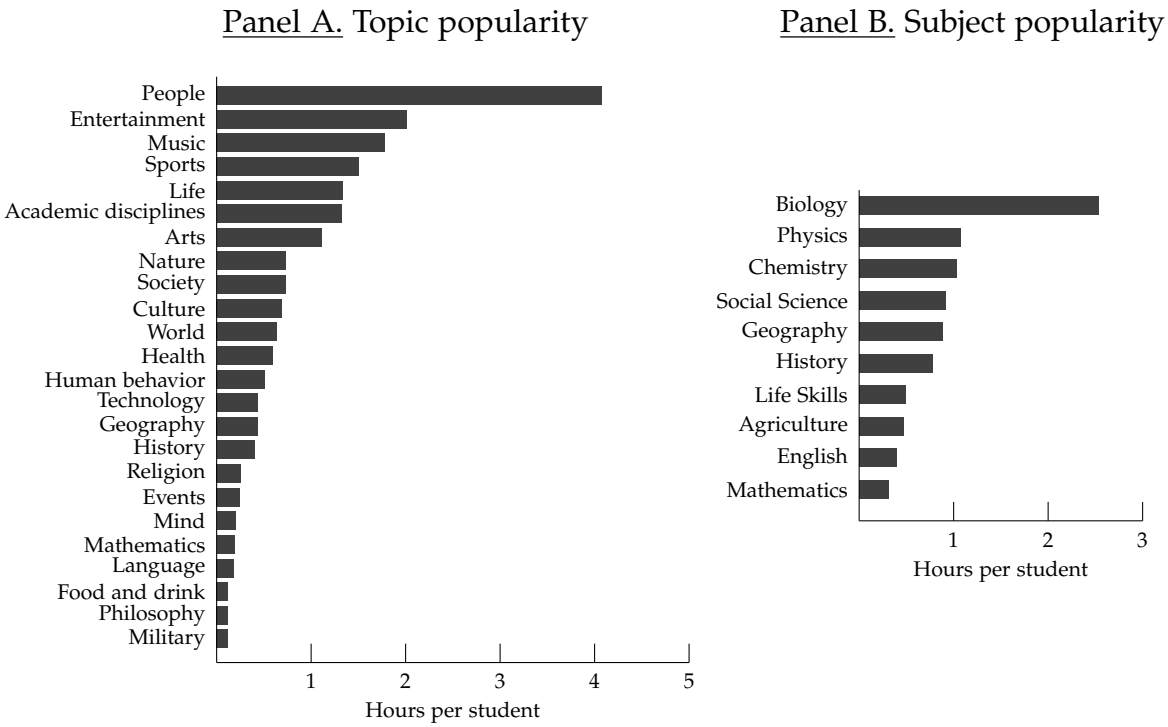



*Notes:* Density of browsing hours, treatment students only, aggregated over one academic year. The digital library was open for 20-22 weeks, from November 2017 to June 2018, excluding Christmas and Easter vacations. Vertical lines are the average hours spent browsing. Panel A: Average is 28.6. Panel B: Average is 31.2 for high achievers and 27.1 for low achievers.

Panel A in Figure 2 presents the 24 most common Wikipedia Browsing topics according to time spent. The typical student spread their browsing time across several different topics (see Panel A of Appendix Figure A2 for detail on within-student variation in topics). The most popular topic is "People", with an average of four hours per student. This topic includes politicians, musicians, athletes, and other individuals of interest. Many popular topics including "Life", "Academic disciplines", "Arts", and "Nature" overlap with school subjects. We will identify school-related pages using a narrow classification in Section 3.5.

than one narrow subcategory. For example, the page on Barack Obama is associated to over 40 subcategories such as "Presidents of the United States", "University of Chicago Law School faculty" and "Grammy Award winners". By following different paths through the Wikipedia category tree, we might categorize it under more than one top-level category. We select the top-level category that appears most often at the top of these paths. For example, the topic we assign to Barack Obama's Wikipedia page is "People". Additional detail is provided in Appendix A.

Figure 2: Hours Spent Browsing Wikipedia by Topic and School Subject



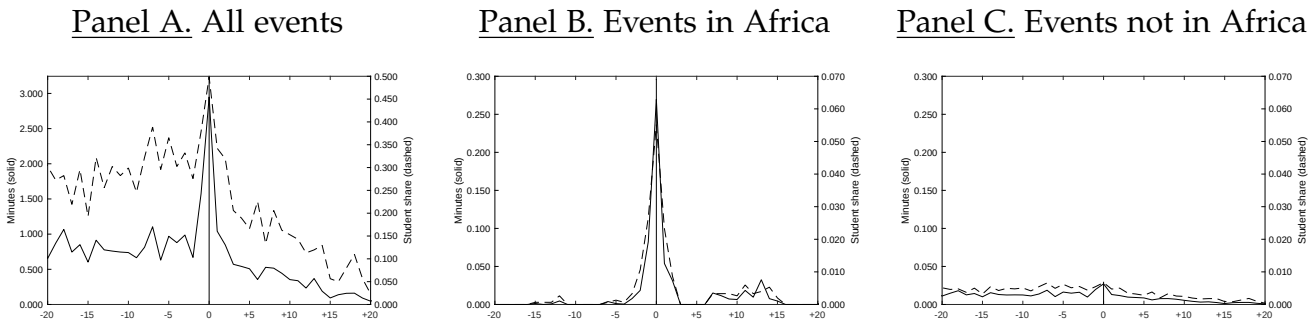

*Notes:* Panel A: Browsing hours per topic, per student, aggregated over one academic year. See Appendix A for details on topic classification. The topics Business, Concepts, Crime, Economy, Education, Energy, Government, Humanities, Knowledge, Law, Objects, Organizations, Politics, Science, and Universe are excluded from the figure and are less than 0.12 hours. Panel B: Browsing hours per school subject, per student, aggregated over one academic year.

## 3.3 News and World Events

In this section, we ask whether students use Wikipedia to learn about the news. Indeed, the popularity of "People" pages may indicate interest in individuals at the center of a news story. Other popular news sources, such as social media and online news sites, are often biased and sometimes inaccurate (Chung, Nam and Stefanone, 2012). By comparison, news articles on Wikipedia are often impartial and accurate (Lih, 2004). If provided with this type of fact-based resource, will young people use it to read about world events?

We examine student browsing in the time leading up to or immediately following the event. Students might learn about news events from Wikipedia itself (as Wikipedia's main page has a section on news), from teachers, or during term breaks. We use

Figure 3: Wikipedia Browsing for News about World Events in 2017-18




*Notes:* Panel A: Left axis (solid line) shows total average browsing minutes per student on pages related to full set of worldwide events. Right axis (dashed line) shows share of students that visited pages associated to at least one event. Panels B and C: Left axis (solid line) shows average number of minutes per student and event. Right axis (dashed line) shows average share of students that visited pages associated to a single event. All events from November 2nd 2017 to May 9th 2018 as reported in https://en.wikipedia.org/wiki/2017 and https://en.wikipedia.org/wiki/2018 are included, with the 20 weeks before and after they occurred. See Appendix B for details on classification of news events. Week of the event is set at zero. Negative (positive) numbers on the x-axis are weeks before (after) the event.

Wikipedia's comprehensive list of 64 major world events that happened after the start of the intervention and prior to the start of the endline surveys (November 2nd, 2017 to May 9th, 2018).[36]

When we look at time spent on pages related to a particular news event, we observe a clear spike during the week the event occurred (Panel A of Figure 3). The average student spent 2.9 minutes browsing these news stories, aggregated over 64 events. While few students read about any particular event, most students searched for at least one. This greatly underestimates total interest in the news, as most news events, and particularly news stories from Africa and Malawi, are not included among Wikipedia's top 64 stories. The spike in browsing emerges for both African and non-African events (Panels B and C of Figure 3). Students spent 10 times longer on news events taking place in Africa (Panel B of Figure 3).

[36]Source: https://en.wikipedia.org/wiki/2017 and https://en.wikipedia.org/wiki/2018. We consider Wikipedia pages that are related to each event prior to May 11th, when Endline A took place. Details of the procedure to associate events to Wikipedia pages can be found in Appendix C. The list of events can be found in the supplementary materials.

## 3.4 Sex and Sexuality

Sex and sexuality are important topics for young people, and while teenagers are often curious, the information they obtain is not always accurate. Misinformation has serious consequences. It can lead to unwanted pregnancy, inappropriate behavior, and HIV infection. Wikipedia contains detailed, accurate, and up-to-date information on human reproduction, sexuality and sexual health. Yet, while informative, some pages related to sex and sexuality might serve primarily as entertainment for students who otherwise have no internet access. Moreover, policymakers, educators and parents might not view unlimited information access as desirable, if it leads to beliefs, attitudes, and sexual behaviors they wish to discourage. These views likely vary and depend on the cultural context. In 2013, Malawi became a signatory to the *UNESCO Ministerial Commitment on Comprehensive Sexuality Education and Sexual and Reproductive Health Services for Adolescents and Young People in Eastern and Southern Africa* (Likupe et al., 2021), which includes a commitment to provide "comprehensive, life skills-based HIV and sexuality education [...] by providing scientifically accurate, realistic, non-judgmental information". The Malawian secondary school curriculum includes clear objectives to inform and educate students on safe reproductive health, and topics from the Life Skills syllabus include: "differences between sex, sexuality and gender", "structures that support victims of sexual harassment and abuse", "reproductive health problems: teenage pregnancy, fistula, abortion, contracting STIs including HIV", "discussing myths about sexuality", and "analyzing sources of unreliable information about sex and sexuality". In practice, however, teachers might not have the resources, training, or desire to discuss these topics fully. In Section 3.5, we will explore the overlap between the school syllabus and sex and sexuality topics browsed by students.

We find that the average student spent 2.0 hours, or 7 percent of their time on pages related to sex and sexuality, broadly defined, as determined by the Wikipedia categories for "Human Reproduction", "Human Sexuality", "Sexual Health", and "Sexuality and

Society".[37] Comparing this to Figure 2, we see that sex and sexuality would place third among general interest topics. The page for "Sexual Intercourse" is the most popular page within this topic and across all Wikipedia pages.

## 3.5 The School Syllabus

While Wikipedia has the potential to impact student learning in various direct and indirect ways, here we focus on whether students use Wikipedia to study their school subjects directly. Wikipedia has content on every academic subject, and might replace textbooks, which are often in short supply. The findings of this section will inform our later discussion of results on academic performance and student time use.

By manually mapping the Malawian secondary school syllabus to specific Wikipedia pages and narrow subcategories, we can show that students do use Wikipedia as a study tool.[38] We manually map the Malawian secondary school syllabus to specific Wikipedia pages and narrow Wikipedia subcategories from the category tree described in Section 3.2. For example, the subcategory for "Circulatory System" matches a topic in the Biology syllabus, and we include it in our list of syllabus subcategories. We do not include broad categories such as "Biology" or "History". If a Wikipedia page exactly matches a topic for a particular school subject, or belongs to a syllabus subcategory, we classify it as directly related to that subject syllabus. We further discuss this classification, as well as other potential classifications in Appendix A.

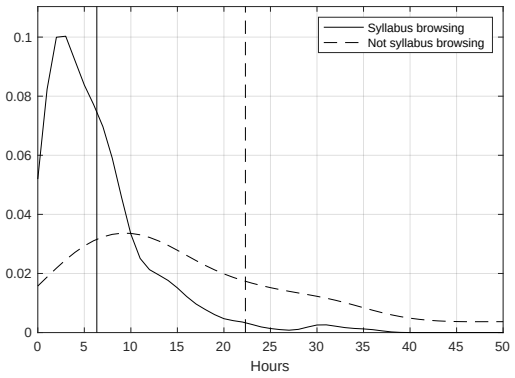
Students face a tradeoff between browsing general interest pages and syllabus pages, and on average, students allocate 22 percent of their browsing time to pages directly related to the syllabus. The average student spent 6.3 hours on pages related to the school syllabus, with some students spending as many as 20 hours on school subjects (Panel A of Figure 4). Comparing this to Figure 2, we see that students spent more time

[37] Additional details, as well as examples of page classifications and alternative definitions are available in Appendix A.

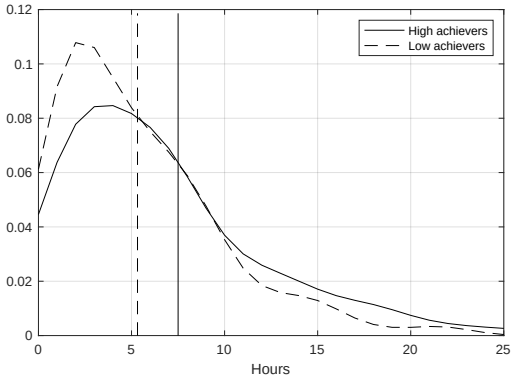
[38] The 2017-2018 Malawi secondary school syllabus can be provided by the authors upon request.

Figure 4: Hours Spent Browsing Pages Related to the School Syllabus

Panel A. Hours on syllabus




Panel B. High and low achievers




*Notes:* Density of browsing hours, across treatment students only, aggregated over one academic year for school syllabus-related pages. Panel A: Hours on syllabus- and non syllabus-related Wikipedia pages. Vertical lines are average hours spent browsing (6.3 on syllabus and 22.3 on non-syllabus). Panel B: High (low) achievers defined as above (below) median exam scores at the baseline. Vertical lines are the average hours spent browsing syllabus pages (7.5 for high achievers and 5.3 for low achievers).

on school subjects than on any general interest topic. High achievers spend more time on the syllabus than low achievers (7.5 versus 5.3 hours). We will discuss these patterns further in relation to the intervention's impact on academic performance in Section 5.

We expected Wikipedia to be useful, and used, for Biology, and students indeed browsed Biology pages significantly more than any other subject (2.5 hours on average, Panel B of Figure 2). This was followed by other science subjects (Physics and Chemistry, one hour each), humanities (Social Science, Geography, History, Life Skills and Agriculture, thirty minutes to an hour), and, finally, English and Mathematics (below thirty minutes each).[39] The average student spread their study time across five different school subjects (see Panel B of Appendix Figure A2).

There is overlap between the school syllabus and topics related to sex and sexuality. One third of the time students spend on sex-related topics involves pages that can be directly linked to the school syllabus. These topics are frequently part of the Biology syllabus (e.g. "Sexual Reproduction") or the Life Skills syllabus (e.g. "Birth Control").

[39]Students spent more than twice as much time (a simple t-test generates a 95 percent confidence interval of 1.3 to 1.6 more hours) on Biology pages than on Physics pages (the next most popular subject).

However, sex and sexuality appear to be of particular interest to the students for reasons that are likely unrelated to their studies. If we exclude all sex-related topics, the average time spent on pages related to the school syllabus drops from 6.3 to 5.7 hours. However, Biology remains by far the most popular subject, with 2.1 browsing hours on average.

### 3.6 Discussion of Student Browsing Patterns

As we examine student browsing patterns, the following stylized facts emerge. First, the intervention was effective in encouraging students to read. The average student used the new resource intensively, and spent one hour and twenty minutes per week reading articles on Wikipedia. Second, individual students have broad interests: they visited a multitude of pages on a variety of topics, mostly not related to their studies. Third, students showed an interest in using Wikipedia to learn about important topics such as world events and sex and sexuality. Finally, by matching the Wikipedia pages to the school syllabus, we find that approximately a fifth of their time was spent on pages directly related to their school subjects. Students appear to find Wikipedia useful as a study tool, especially for Biology.

## 4 Using Digital Technology to Find Information

In this section, we show that treatment students became comfortable with information technology, and learned to use it to quickly find accurate information. We show that students prefer Wikipedia to other information sources, and that access to Wikipedia allowed treatment students to find information about news events, as well as information about academic subjects that their peers could not find using school resources.

## 4.1 Data and Empirical Strategy

We conducted two endline surveys.[40] Endline Survey A took place between May and June, 2018. It had two versions: a short version that was administered to all students in Forms 2, 3, and 4, and a longer version that was administered to students in the treatment group and to the subsample of control students who were randomly selected for supplementary surveys. Endline Survey B was a survey administered to treatment students and to the subsample of control students. Endline B took place after Endline A, in June and July, 2018.

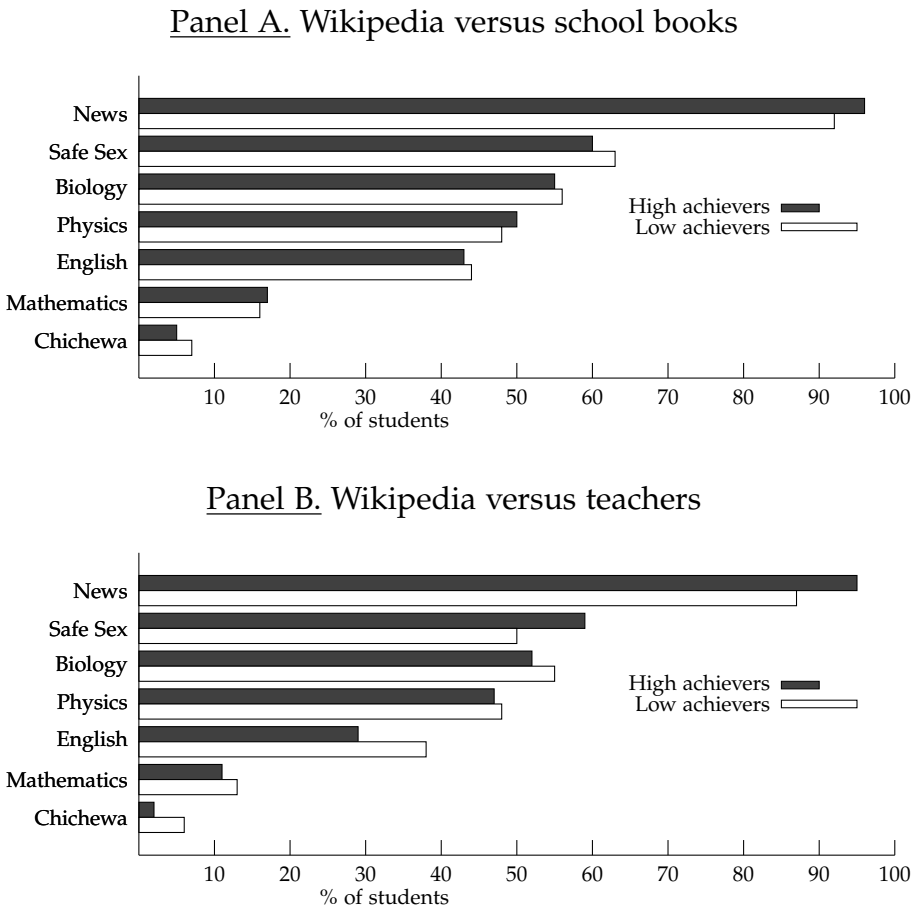
We have a low rate of attrition for both Endline Surveys A and B (Panel B of Table 1). The attrition rate for Endline A is 5 percent in both the treatment group and the subsample control group. There is significantly higher attrition in the full control group (8 percent), and we therefore include Lee (2009) bounds when interpreting the results on time use and participation in Section 5.3. The attrition rate for Endline B is 8 percent, with no differential attrition.

Data from Endline Survey B shows that treatment students found Wikipedia accessible and useful. Figure 5 plots the percentage of treatment students who prefer Wikipedia to their textbooks or teachers, respectively, by topic. Most students prefer Wikipedia to either books or teachers for general interest subjects such as news events and safe sex. They also prefer Wikipedia to their Biology books and teachers, with a slightly higher preference for Wikipedia among low achievers (the difference is not statistically significant). Overall, more than two-thirds of treatment students believe that information on Wikipedia is easier to find, easier to use, and more trustworthy than information on the broader internet (beliefs are similar for low and high achievers, see Appendix C).

We investigate the impact of the intervention by regressing survey outcomes on the

[40] We include the complete list of questions from the endline surveys in the supplementary materials.

Figure 5: Student Preference for Wikipedia by School Subject




*Notes:* Percent of treated students that prefer Wikipedia over school books and teachers respectively. At endline, students are asked to rank sources according to the "best place to find information" for each topic. High (low) achievers defined as above (below) median exam scores at the baseline.

treatment variable. We estimate the following equation:

$$y_i = \beta \text{Treatment}_i + \sigma_s + \varepsilon_i. \quad (1)$$

Here, $y_i$ is a survey outcome measure for student $i$ at endline. $\text{Treatment}_i$ is an indicator for treatment status. $\varepsilon_i$ is a mean-zero error term. To estimate our standard errors consistently, we also include a fixed effect for the stratification bin, $\sigma_s$, where $s$ is the

stratification bin for student $i$.[41] We report heteroskedasticity-robust standard errors, as well as randomization inference p-values.[42]

We use ordinary least squares to estimate the treatment effect $\beta$. Because treatment status $\text{Treatment}_i$ is randomly assigned, we expect the error term to be mean-independent of treatment status, $\mathbb{E}(\varepsilon_i|\text{Treatment}_i) = 0$. Therefore, in the absence of spillovers, the OLS estimate $\hat{\beta}$ is unbiased. For the outcomes in this section, positive spillovers are likely, especially from treated to control students (see Section 6.1). In this case, $\hat{\beta}$ is an underestimate of the effect of the intervention. The nature of spillovers on academic performance outcomes is likely to be different, and will be examined in Section 5.

## 4.2 Results

The intervention helped students learn how to use an internet-enabled device to find information quickly and easily. During the Endline B survey, the enumerator handed the student an internet-enabled device equipped with several internet applications including both Wikipedia and Google. The student was asked to find the number of stars in the Milky Way. Treatment students are more likely to choose Wikipedia over other internet information sources: they were twice as likely to use Wikipedia for this task (Column 1 of Table 2). These results are large and significant for both low and high achievers. Most treatment students (58 percent) are able to find the correct answer within 2 minutes (Column 2 of Table 2). Only 39 percent of control students succeed.

Next, we show that students with access to the digital library have an advantage over their peers when it comes to finding information about both the news and about academic subjects, which suggests that the digital library may be useful as a study resource, over and above the resources provided by the school. We used a small experiment to

[41] This is necessary to produce consistent standard errors (Bruhn and McKenzie, 2009).

[42] We randomize at the individual level, and therefore do not report cluster-robust standard errors (Abadie et al., 2017). Randomization inference p-values are based on 10,000 replications.

Table 2: Ability to Find Information

| | (1) Milky way phone test (opened Wikipedia) | (2) Milky way phone test | (3) News quiz | (4) Academic quiz |
|---|---|---|---|---|
| Panel A. Overall effects | | | | |
| Treatment | .253*** | .186*** | .089** | .108*** |
| | (.038) | (.039) | (.042) | (.041) |
| | p = .000 | p = .000 | p = .035 | p = .009 |
| Panel B. Heterogeneous treatment effects | | | | |
| Treatment x low achiever | .233*** | .183*** | .029 | .096 |
| | (.052) | (.053) | (.058) | (.060) |
| | p = .000 | p = .001 | p = .622 | p = .111 |
| Treatment x high achiever | .275*** | .190*** | .152** | .120** |
| | (.055) | (.059) | (.060) | (.056) |
| | p = .000 | p = .001 | p = .013 | p = .034 |
| Units | Binary | Binary | Binary | Binary |
| Mean of dependent variable in control | .212 | .392 | .513 | .567 |
| Strata FE | yes | yes | yes | yes |
| Number of students | 549 | 548 | 535 | 538 |

*Notes:* Treatment effects on student ability to find information. "Milky way phone test" refers to the test whereby students were asked "How many stars are there in the Milky Way?" and were allowed to consult the internet during the survey to find the answer. (1) is an indicator equal to one if the student opened the Wikipedia app during the test. (2) is an indicator equal to one if the student was correct within two minutes of search. (3) and (4) are indicators equal to one if at Endline B, the student correctly answered the quiz question that was provided during Endline A. Questions were student-specific and correct answers were incentivized. High (low) achievers defined as above (below) median exam scores at the baseline. The sample is students in the treatment group and in the subsample of the control group with supplementary surveys. We include strata fixed effects. Randomization was stratified by school, form, above median achievement and past internet use. Robust standard errors in parentheses. * p<.10, ** p<.05, *** p<.01. Randomization inference p-values based on 10,000 replications denoted as "p =".

capture a student's ability to find information at school. In Endline A, each student was given two quiz questions: a news question and an academic question.[43] These questions were different for every student. Students were told that two weeks later, during Endline B, they would be given a prize for each correct answer. The digital library was open between the two surveys. Students in the treatment group are 9 percentage points more likely to find the answer to the news question (Column 3 of Table 2). They are also 11 percentage points more likely to correctly answer the academic question (Column 4 of Table 2). This is more surprising, as all students had access to the school library, their notes and their teachers. The effect is only statistically significant for high achievers. These outcomes are likely subject to spillovers; indeed we find that control students often asked treatment students to search on their behalf. This is discussed in Section 6.1.

Here and in Appendix C we test multiple closely related hypotheses related to online information. Pooling all outcomes, including heterogeneous treatment effects, we calculate sharpened $q$-values using the Benjamini, Krieger and Yekutieli (2006) false discovery rate method, following Anderson (2008). All average and heterogeneous treatment effects in Tables 2 and A4 are robust to this multiple inference method at the five percent level, with the exception of the (insignificant) impact on low achievers' news quiz scores in Table 2, Column 3.

# 5 Academic Performance

In this section we investigate the impact of restricted internet access on academic performance, as well as student time use, class participation, and aspirations. Wikipedia might improve English language skills, and English exam scores, by offering compelling and accessible reading material. It might be used directly as a study tool in place of, or in support of, textbooks, notes and teachers. We saw in Section 3 that many students

[43]The student drew each question from a hat, and kept the slip of paper. See the supplementary materials for a list of sample questions.

use Wikipedia as a study tool, especially for Biology. Wikipedia content might inspire students to higher aspirations, or shape student interests. There is also the potential for a negative impact, if Wikipedia acts primarily as a form of entertainment or distraction. Given the share of browsing time devoted to non-syllabus topics (Section 3.5), this is a potential concern.

## 5.1 Data and Outcomes

Our primary outcomes are English and Biology exam scores in the final term.[44] We selected these two subjects as primary outcomes for several reasons. If Wikipedia serves as a literacy intervention, English language skills should improve over time and impact English exam scores.[45] Biology exams require students to absorb a large amount of information, and Biology students are likely to benefit from additional study materials. Our browsing and survey data support the view that students find Wikipedia particularly useful for Biology. Recall that students spent more time on pages related to Biology than on any other school subject. Moreover, at endline we elicited student preferences for Wikipedia by school subject, and find that most treated students prefer Wikipedia to their Biology books and teachers respectively (Figure 5). This preference for Wikipedia does not exist for other subjects. Finally, at baseline, English and Biology are the most popular subjects in our sample, as measured by enrollment and stated preference. Biology is especially important for students' career prospects. At baseline, a majority of students aspired to become doctors, nurses, or other healthcare professionals. Many of the students who pass their final exams do go on to college programs in nursing, medicine, or other health specialties. This interest in Biology reflects career prospects for Malawian secondary school graduates more generally; the schools in our sample do not

[44] We pre-registered term 3 English and Biology scores as our two primary outcomes (AEA RCT Registry number AEARCTR-0003824).

[45] In our setting, English exam scores measure English language ability. We include a sample English exam in the supplementary materials.

have any particular focus on Biology or healthcare.

We also measure impacts on other academic subjects including Mathematics, Chichewa (a local language), other science subjects (Physics and Chemistry) and the humanities. We did not expect to see a positive impact on these subjects. Mathematics, Physics and Chemistry are primarily skill based. While Wikipedia does have a version in Chichewa, it hosts only a few hundred pages, none of which were visited by students. The humanities are unpopular with students at baseline, as measured by enrollment and stated preference. We therefore did not include any of these subjects as primary outcomes. However, we might expect a negative impact if students shift time away from those subjects towards English, Biology, or online distraction.

To measure academic performance, we use administrative data on school exam scores, and national exam scores for Form 4 students. We collected exam scores for all subjects in all three terms, as well as end-of-year scores for the year before the intervention began.

For each core subject (English, Biology, Mathematics and Chichewa), we construct a separate outcome variable $y_i$ representing student $i$'s final exam score in that subject, standardized within the form and school. Other subjects are offered as electives, or only in certain forms or schools. We combine similar subjects using an index measure that assigns weight to non-missing values. We construct an outcome for other science subjects (Physics and Chemistry) and a separate outcome for subjects which we loosely define as humanities (Social Science, Geography, History, Life Skills and Agriculture).[46] Administrative data is missing for a few exam scores, as some students drop out or miss an exam. We are missing data for approximately 7 percent of students (Panel B of Table 1).

We also construct two measures of absolute overall performance, based on the mea-

[46]For Form 4 students we use national exam scores. We standardize scores by subtracting the mean and dividing by the control group standard deviation within each school and form. We then subtract the overall control group mean (across forms and schools). We are guided by Anderson (2008) in our construction of summary indices. Each index variable is a weighted mean of standardized scores. This procedure gives less weight to highly correlated outcomes and outcomes with missing values.

sures used by the Malawi National Examination Board (MANEB). Form 4 students receive a point-score for each subject exam, with points ranging between 1 (top score) and 9 (fail). The total number of points is determined by adding up the score on the English exam and the top 5 other subjects. A student passes secondary school if they pass English and five other subjects, with a "credit" in at least one subject (a score of 6 points or less). We use the MANEB conversion between percentage scores and points to define proxy measures for students in Forms 2 and 3.

## 5.2 Empirical Strategy and Main Results

We estimate the effects of the intervention on exam scores for each subject in the final term.

$$y_i = \beta \text{Treatment}_i + \delta \left( y_{i0} \times \text{Data}_{i0} \right) + \delta_0 \text{MissingData}_{i0} + \sigma_s + \varepsilon_i \quad (2)$$

Here, $y_i$ is the measure of academic performance for student $i$ in term 3. $\text{Treatment}_i$ is an indicator for treatment status. $\varepsilon_i$ is a mean-zero error term. To improve precision, we control for the baseline measure of the outcome, $y_{i0}$, taken from term 3 of the previous school year.[47] We use indicators for missing baseline scores: $\text{Data}_{i0}$ and $\text{MissingData}_{i0}$ are indicators for whether or not we have baseline data $y_{i0}$ for student $i$. We include a fixed effect for the stratification bin. We report robust standard errors, as well as randomization inference p-values based on 10,000 replications. Our parameter of interest is the average treatment effect $\beta$.

Because treatment status $\text{Treatment}_i$ is randomly assigned at the student level, we expect the error term to be mean-independent of treatment status, $\mathbb{E}(\varepsilon_i | \text{Treatment}_i) = 0$. Therefore, in the absence of spillovers, the OLS estimate of $\beta$ is unbiased.

We also estimate heterogeneous treatment effects by baseline achievement, interacting

[47] In Appendix Tables A5 and A6 we report results without controlling for baseline exam scores.

the treatment variable with an indicator for high achievement at baseline. We define high achievement as above median average score in English and Biology, which corresponds to one of our stratification variables.

Spillovers are possible in our setting, from treatment students to other treatment students or to control students. While information is likely to be shared between treatment and control students, any impact on English language skills or Biology exam scores is likely to be small without direct access to the reading material. In Appendix Table A7 we provide some evidence that this is indeed the case, using a specification that controls for spillovers from treated study friends.[48] A different type of spillover may operate through teacher behavior, however, given the sparse treatment, and standardized syllabus and exams, there was little opportunity for teachers to adapt to the intervention. We discuss this further in Section 6.1.

We find a significant impact on English exam scores, overall ($0.10\sigma$) and for low achievers ($0.20\sigma$), and a significant impact on Biology scores for low achievers ($0.14\sigma$, see Table 3). We find no significant impact on high achievers in either subject. We also estimate alternate heterogeneous treatment effect specifications, and find similar results (Appendix Tables A8 and A9).

For our primary outcomes, including heterogeneous treatment effects, we again calculate sharpened $q$-values using the Benjamini, Krieger and Yekutieli (2006) false discovery rate method. The three significant estimates in Table 3 (the average treatment effect on English scores and heterogeneous treatment effects on English and Biology for low achievers) are robust to this multiple inference method at the ten percent level, with $q < 0.07$ for all three estimates.

[48]The spillover effect specification in Appendix Table A7 contains controls for the number of named study friends at baseline, treated study friends and treated study friends interacted with being a control student. It is difficult to fully capture spillovers using a baseline network, and doing so in our case introduces noise. In fact, our friendship networks are endogenous to the treatment itself, a finding which will be explored in depth in future research. We choose to rely on study friend networks because Malawian schools assign students to "study circles" at the beginning of the school year, and so such friendship networks are less responsive to the intervention.

Table 3: Treatment Effects on Exam Scores, Primary Outcomes

| | (1) English | (2) Biology |
|---|---|---|
| Panel A. Overall effects | | |
| Treatment | .103** | .063 |
| | (.050) | (.047) |
| | p = .046 | p = .192 |
| Panel B. Heterogeneous treatment effects | | |
| Treatment x low achiever | .195** | .143** |
| | (.076) | (.067) |
| | p = .016 | p = .043 |
| Treatment x high achiever | .003 | -.025 |
| | (.062) | (.064) |
| | p = .964 | p = .707 |
| Mean of dependent variable in control | .000 | .000 |
| Strata FE | yes | yes |
| Number of students | 1412 | 1406 |

*Notes:* Treatment effects on final exam scores. High (low) achievers defined as above (below) median exam scores at the baseline. We include a control for baseline exam score, an indicator for missing baseline score, and strata fixed effects. Randomization was stratified by school, form, above median achievement and past internet use. Robust standard errors in parentheses. * p<0.10, ** p<0.05, *** p<0.01. Randomization inference p-values based on 10,000 replications denoted as "p =".

We do not find any impact, positive or negative, on other school subjects (see Table 4, Columns 1 to 4). Average treatment effects are between $-0.03\sigma$ and $0.04\sigma$ for Mathematics, and science and humanities subjects. We cannot rule out a small negative impact on Chichewa; while insignificant, the estimate is $-0.07\sigma$.

Finally, we see positive, though statistically insignificant impacts on absolute measures of overall performance. In Table 4, Column 5, we report the impact on the total number of points awarded to students, as defined by MANEB. Fewer points represent a higher score, and in Table 4 we have scaled this outcome by $-1$ for ease of interpretation. Treatment students score 0.2 fewer points on average, an approximate $0.02\sigma$ improvement. This effect is larger, though still insignificant for low achievers, whose scores improve by 0.5 points or approximately $0.05\sigma$. The impact on pass rates is also insignificant, though point estimates are positive (Table 4, Column 6). Treatment students are 3 percentage points more likely to pass the year, and low achievers are 6 percentage points more likely to pass (significant at the 10 percent level).

Table 4: Treatment Effects on Exam Scores, Other School Subjects

| | (1) Science | (2) Human. | (3) Math | (4) Chichewa | (5) Points | (6) Pass |
|---|---|---|---|---|---|---|
| Panel A. Overall effects | | | | | | |
| Treatment | -.029 | -.001 | .042 | -.066 | .206 | .029 |
| | (.047) | (.050) | (.044) | (.057) | (.378) | (.020) |
| | p = .520 | p = .988 | p = .331 | p = .239 | p = .577 | p = .139 |
| Panel B. Heterogeneous treatment effects | | | | | | |
| Treatment x low achiever | .016 | .100 | .105* | -.071 | .493 | .060* |
| | (.070) | (.070) | (.062) | (.079) | (.585) | (.032) |
| | p = .803 | p = .142 | p = .084 | p = .386 | p = .379 | p = .075 |
| Treatment x high achiever | -.076 | -.112 | -.022 | -.060 | -.106 | -.001 |
| | (.062) | (.070) | (.061) | (.083) | (.467) | (.022) |
| | p = .213 | p = .061 | p = .734 | p = .438 | p = .830 | p = .962 |
| Mean of dependent variable in control | .000 | .000 | .000 | .000 | -26.448 | .867 |
| Strata FE | yes | yes | yes | yes | yes | yes |
| Number of students | 1370 | 1396 | 1376 | 1398 | 1399 | 1381 |

*Notes:* Treatment effects on final exam scores. Science is a summary index of Chemistry and Physics. Humanities is a summary index of Agriculture, Geography, History, Life Skills and Social Science. Points is a measure of the students final overall grade. For each subject, the percentage scores is converted to a number of points between 1 and 9, where 1 is the best score, and 9 is the lowest score. The conversion is provided by the Malawi National Examinations Board (MANEB). The total number of points, also determined by MANEB, is the number of points obtained in English plus the number of points in the five other best subjects, where the best score is 6 points and the worst possible score is 54. We multiply the total number of points by -1 to ease interpretation of the coefficients in (5). Pass is an indicator equal to one if a student passes the school year. To pass the school year, students must pass their English course and five other courses and obtain a score of 6 points or less in at least one course. High (low) achievers defined as above (below) median exam scores at the baseline. In all regressions we include a control for the baseline measure of the outcome, an indicator for missing baseline measure, and strata fixed effects. Randomization was stratified by school, form, above median achievement and past internet use. Robust standard errors in parentheses. * p<0.10, ** p<0.05, *** p<0.01. Randomization inference p-values based on 10,000 replications denoted as "p =".

Most exams are marked by the students' teachers, which could bias our results up or down. On the one hand, there could be teacher demand effects; teachers might grade treated students differently from control students. However, each teacher teaches hundreds of students, and it would be difficult for them to keep track of which students took part in the intervention. If teachers did know which students were taking part, and this explained the impact on scores, we would not expect stark differences by subject and baseline achievement. On the other hand, exams might not fully capture the impact of the intervention, if students improve their subject knowledge in ways that exams do not measure. Or, teachers might grade exams based on their own knowledge or outdated learning materials, and might therefore grade correct answers that students learned online as incorrect. This would bias our results towards zero.

### 5.3 Time Use, Class Participation and Aspirations

We next examine student time use across different activities, to determine whether treatment students substituted away from study time to spend time in the digital library. We collected time use data from all students in Endline A, while the digital library was still in operation. We asked students to recall their time spent on specific activities, day by day, for the three days preceding the survey. We then classify time use as studying, recreation or sleep.[49] Study time includes time the students spent studying in the digital library, but not other browsing time. We use Equation (1) to estimate the impact of the intervention on study time, recreation time, and sleep. Because Endline A was subject to differential attrition in the full control group, we also report Lee (2009) bounds.

[49] We compute average daily study time by summing time spent studying alone and time spent studying with others. To construct a measure of time spent on recreational activities, we sum the time spent hanging out with friends, in school clubs, religious activities, sports activities and any other activities. Finally, we asked students the time at which they woke up and went to bed, and compute average awake time over the previous three days.

Table 5: Time Use, Participation in Class and Career Goals

| | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|
| | Time use (hours per day) | | | Participation in class (per day) | Career goal change |
| | Study | Recreational | Awake | | |
| Panel A. Overall effects | | | | | |
| Treatment | -.029 | -.286*** | .007 | -.025 | .031 |
| | (.071) | (.078) | (.086) | (.159) | (.042) |
| | p = .721 | p = .004 | p = .924 | p = .877 | p = .557 |
| Panel B. Heterogeneous treatment effects | | | | | |
| Treatment x low achiever | -.038 | -.348*** | -.016 | .118 | .077 |
| | (.098) | (.100) | (.123) | (.231) | (.058) |
| | p = .749 | p = .014 | p = .886 | p = .604 | p = .293 |
| Treatment x high achiever | -.019 | -.220* | .033 | -.179 | -.014 |
| | (.104) | (.114) | (.119) | (.218) | (.062) |
| | p = .865 | p = .132 | p = .767 | p = .427 | p = .857 |
| Mean of dependent variable in control | 1.937 | 1.940 | 1.938 | 1.937 | 2.096 |
| Strata FE | yes | yes | yes | yes | yes |
| Day-of-the-week FE | yes | yes | yes | yes | yes |
| Number of students | 1402 | 1396 | 1398 | 1402 | 542 |

*Notes:* Treatment effects on time use and participation in class. (1), (2) and (3) refer to the time spent on studies, recreational activities and not sleeping, respectively, and averaged over the three days prior to the interview. Study time is the sum of the answers to the questions "How much time did you study alone?" and "How much time did you study with others?". Recreational time is the sum of the answers to the questions "How much time did you hang out with friends?", "(...) in a school club?", "(...) in religious activities?", "(...) sports activities?" and "(...) other activities?". Awake time is the duration between waking up and going to sleep at night. We calculate Lee (2009) bounds in (1), (2) and (3) of Panel A to assess the robustness with respect to differential attrition. For recreational time, the bounds are [-.361, -.222] and both are statistically significant at the 5% level; for study time, the bounds are [-.149,.020]; awake time, [-.104,.090]. (4) counts the number of times that students responded that they raised their hands in class to ask a question, also averaged over the three days prior to the survey. (5) shows change in career goal between baseline and endline surveys, defined as a change in career category or precision (e.g. "doctor" to "surgeon" is considered a change). High (low) achievers defined as above (below) median exam scores at the baseline. (1)-(2) include baseline controls and all regressions include strata and day-of-week fixed effects. Robust standard errors in parentheses. * p<0.10, ** p<0.05, *** p<0.01. Randomization inference p-values based on 10,000 replications denoted as "p =".

It appears that students did not take time away from their studies to visit the digital library, and did not cut back on sleep (Columns 1 and 3 of Table 5). Rather, the digital library crowded out time spent hanging out with friends, playing sports, and attending religious activities. Treated students spent 0.3 fewer hours per day on recreation (Column 2 of Table 5), which roughly corresponds to time spent browsing Wikipedia for general interest topics.[50] Low and high achievers reallocated their time in a similar way (Columns 1 to 3 in Panel B of Table 5).

Access to Wikipedia might affect class participation by increasing student confidence, motivation, or interest. In Endline A, we asked each student to report the number of times they raised their hand in each class, day by day, over three days. We then take the average number of times they raised their hand over the three days. We estimate Equation (1).

We do not find evidence for a change in class participation. On average, a student raises their hand three times per school day. There is no significant difference between treatment and control students, nor by achievement level, though the point estimate of the treatment effect is positive for low achievers (Column 4 of Table 5).

Finally, Wikipedia might affect student aspirations, by helping students plan for a career or introducing new role models. We ask students, at baseline and in Endline Survey B, which career they hope to have in the future. In Endline B, we also ask students to name the college they will most likely attend, as well as their dream college.

We define an indicator variable for a change in career choice between baseline and endline.[51] We use Equation (1) to estimate the impact of the intervention on the likelihood of a change in career aspirations.

The intervention does not appear to cause students to change their career aspirations, regardless of baseline achievement level, though the point estimate is positive for low

[50] Time spent on general browsing (but not studying) in the digital library is an omitted category.

[51] The outcome variable is coded as equal to one if the individual reported any career choice change between baseline and endline surveys. This can arise due to change in career as well as a change in precision (for example, "doctor" in the baseline to "neurologist" in the endline).

achievers (Column 5 of Table 5). At endline, treatment students and control students choose similar types of careers, with most aspiring to healthcare positions. In Figure A3 we present the career aspirations of treatment and control students at endline. There are no clear systematic differences. In Panels A and B of Figure A4, we present most likely and dream colleges reported by treatment and control students, and again see no systematic differences. We note that our pool of students had high aspirations at baseline, suggesting limited scope for an increase in self-reported aspirations. At baseline, one third of students hoped to become a doctor, specialist doctor or surgeon.

# 6 Discussion and Conclusion

We find that restricting internet access to Wikipedia affects academic performance through two channels. First, students use the internet intensively, and read articles, in English, on a broad range of topics of general interest. This access to wide ranging reading material, during a full school year, leads to positive gains in English exam scores, especially for low-achieving students. Second, students use the internet as a study tool for Biology, and prefer it to their textbooks. This has a significant impact on exam scores for low-achieving students, whose study time becomes more productive.

## 6.1 Mechanisms

Though students spent more than one hour per week in the digital library, and spent most of that time on topics unrelated to the school syllabus, restricted internet access did not have a negative impact on academic performance. Using 95 percent confidence intervals, we can rule out negative effects for English scores, and effects below $-0.03\sigma$ for Biology. We also find no impact on scores in Mathematics, other science subjects, humanities subjects, or aggregate subject scores, with point estimates between $-0.03\sigma$ and $0.04\sigma$. The impact on Chichewa is insignificant at $-0.07\sigma$. We cannot rule out

small substitution effects from Chichewa, as students shift their attention away from that subject towards subjects taught in English.

Rather, we find a positive impact on English exam scores, which leads us to view student browsing behavior in a different light. English exams are a good test of English language ability; they include multiple choice questions that test student understanding of words, sentences, and grammar, and essay questions. If the restricted internet serves as a literacy intervention, it matters less whether students choose to read about academic topics. In fact, we posit that the internet is effective as a literacy tool precisely because it gives students access to reading material on any topic they choose. The effects may appear large given the browsing behavior of students. However, they are more plausible under the hypothesis that general interest reading, and not only school-related reading, can improve English language skills. Moreover, the effect sizes we observe are not unusual in this literature; Evans and Yuan (2020) find that the median education intervention in low- and middle-income countries increases learning by $0.1\sigma$. Improvements in English language skills may be expected to persist over time, and impact other outcomes over the longer term. We will explore the long run impacts of this intervention in future research.

The impacts on both English and Biology exam scores are larger for low achievers, nearly half of whom had a failing score at baseline. Low achievers with access to Wikipedia score $0.20\sigma$ higher in English and $0.14\sigma$ higher in Biology than their counterparts without Wikipedia access. In the final term, the English score gap between low and high achievers is closed by one fifth due to Wikipedia access. Low achievers spent, on average, slightly less time in the digital library than high achievers. This suggests that heterogeneous treatment effects are not due to differences in use, and are instead due to the fact that reading is more important for students with low baseline ability. Because government boarding schools are academically competitive, a low-achieving student in one of the study schools may in fact better represent the typical Malawian secondary

school student. For this reason, impacts among low achievers are particularly relevant.

We do not find any impact on high achievers for any subject. It appears that for highly literate students, access to online reading material serves as equal part distraction and input to academic performance, with a net effect of zero. While most students rely on school study resources, if high ability students are from wealthier families, they might have the means to purchase books. This might explain why they do not benefit from restricted internet access. However, there is no positive correlation between baseline achievement and socioeconomic status (-0.09), and we find no clear pattern of heterogeneity based on socioeconomic status (Appendix Table A10).[52]

Neither low nor high achievers increased their study time in response to the intervention, yet Biology scores improved for low achievers. Study time must have become more productive, in particular for low achievers. If Wikipedia is easier to use and understand than standard textbooks, this would explain a rapid increase in study time productivity, especially among students who are struggling. At endline, most treatment students stated a preference for Wikipedia over their Biology textbooks and teachers (Figure 5). This is not the case for other subjects, and is consistent with the focus on Biology we saw in the browsing data. Students spent at least twice as much time on Biology as on any other subject (Figure 2). This is also consistent with the small experiment we conducted in Section 4.2, showing that students with Wikipedia access were able to find academic information that control students were not (Column 4 of Table 2).[53] Taken together, these results indicate that online information can serve as a useful and accessible study tool for Biology, and that such a tool is more valuable to low achievers.

Our intervention may have improved academic performance through other channels, for example, by offering an improved study space or affecting student motivation. However, students had access to ample study space outside of class time, including a library

[52]We define high socioeconomic status as having both electricity and running water at home. This describes approximately half of students.

[53]Both low and high achievers report that it is easy to find and understand information on Wikipedia (Appendix C).

and other study areas, and sometimes classrooms. Moreover, students were not permitted to use the digital library unless they were actively browsing the internet. Finally, we only observe an impact on academic performance in English and Biology, school subjects for which Wikipedia offers a potential advantage. This suggests a limited role for motivation or improved study space as a mechanism, but does not rule out the importance of providing a suitable space for quiet browsing. We also note that treated students spent less time on recreation, which might impact non-academic outcomes. We will explore the impact on social networks in particular in future work.

It is plausible that Biology exam scores are subject to positive spillovers from treatment students to both treatment and control students, if students shared the information they learned online. In this case, the effect sizes we estimate understate the true effect of an intervention at scale. English exam scores are less likely to be subject to positive spillovers. If these gains represent an improvement in English language ability, they are likely due to direct exposure to reading material. Spillovers between study friends appear to be small and positive for both Biology and English exam scores. Controlling for baseline study friends increases the average treatment effect and effect for low achievers (see Appendix Table A7).

Exam scores might also be subject to spillovers which may not be captured by the network of study friends. In particular, the intervention could have had real negative impacts on learning for control students due to demotivation. However, we do not see differences in study time or career aspirations. Moreover, it is not clear how demotivation would generate the specific heterogeneity we observe across subjects and achievement levels. In Appendix Table A2, we show that while control students are more likely to view the intervention as unfair, they do not score lower on other measures of ambition, confidence or happiness. Low achievers in the control group do not appear to be worse affected than high achievers according to these measures. A second concern is that if teachers adjust exam scores to fit a particular distribution (i.e. grading on a curve),

an increase in scores for treatment students could lead to a decrease in scores for control students. This would not produce spillovers on real learning outcomes, but would produce negative spillovers on numerical exam scores. If we compare exam scores to that of the previous cohort, such an effect does not appear likely: the distribution of scores shifted up for both control and treatment students (see Appendix Figure A5).

Other outcomes in the paper are likely subject to larger positive spillovers; some types of information spread easily. We find direct evidence for this in the case of the incentivized quiz (Columns 3 and 4 of Table 2). Despite not having access to any online resource, and no alternative source of news, half of control students were able to find the answer to the news question sometime between Endline A and Endline B. 70 percent of the control students who answered correctly reported learning the answer from a friend. The pattern is similar for the academic question (55 percent learned the answer from a friend). It is difficult to measure this type of spillover using a standard specification, as unlike study friendship networks, other types of information-sharing networks evolved significantly in response to the intervention. We will explore this evolution in detail in future work.

Because we randomized access to the restricted internet at the student level, our ability to measure general equilibrium effects is limited. For example, if all teachers and students had access to the internet, teachers might be able to incorporate it into their lesson plans. On the one hand, teachers follow a strict syllabus from the Ministry of Education with little room for adaptation. Moreover, students might find information online that contradicts, or goes beyond, the ideas put forth by textbooks and teachers. This might introduce incoherence and confusion in the classroom. Indeed, in the short term, the introduction of a new technology might disrupt learning. On the other hand, involving teachers typically improves the efficacy of literacy and other primary school interventions. There is less evidence in secondary schools, and this could be the subject of future research.

## 6.2 Cost-Effectiveness, Policy Implications and External Validity

Providing restricted internet access is cost-effective as a substitute for other types of reading materials, and as a literacy intervention in general. We estimate that our intervention, as implemented, costs less than $4 USD per student per month, or $28 USD per $0.1\sigma$ of improvement in English scores. This includes the cost of project management, digital library staff, internet-enabled devices and internet data packages. In many developing countries, Internet.org provides access to Wikipedia for free.[54] Providing access to Wikipedia through Internet.org would reduce the intervention cost to less than $3 USD per student per month. This is approximately equivalent to a school fee increase of 15 to 30 percent, or the cost of increasing the number of teachers per school from 35 to 38 (teachers are specialized by subject, and the average class has around 40 students). The intervention is more cost-effective than programs that provide reading material or financial incentives for reading, as most have no impact. It is also more cost-effective than many computer-aided learning programs.[55] Our cost-effectiveness is similar to many primary school interventions that increase the teacher-student ratio, provide incentives for teacher incentives, or provide remedial lessons, but lower than programs that provide performance incentives to teachers (McEwan, 2015). There are some reasons to expect smaller returns in secondary school, as subject matter increases in difficulty, and students are starting from a higher level of baseline literacy.

Across southern Africa policymakers are facing the question of whether to allow or even provide internet access at school. Where textbooks are in short supply, the internet might serve as a useful and inexpensive substitute, but the full internet can serve as too much of a distraction. It is common for universities and workplaces to restrict access

[54]Internet.org is a partnership between social media and telecommunications firms that provides free access to selected Internet services in poor countries.

[55]For example, Muralidharan, Singh and Ganimian (2019) show that Mindspark, a computer-aided learning platform for primary school students, generates a language score impact at a cost of $39 per $0.1\sigma$. However, they do also find a significant impact on Mathematics scores, suggesting that overall their program might be considered highly cost effective. Indeed, they find that this is more cost effective than default public spending in India.

to certain websites, and secondary schools might do the same. Some online resources may in fact be easier to use and understand than classic textbooks, especially for students who are struggling. For students with lower literacy levels, Wikipedia, with both English and Simple English options, is a low-cost and effective literacy intervention. Not only is the reading material simple and informative, it engages student interest. Students are excited to use the internet, and choose to spend a great deal of time reading. This translates to real gains in English language ability.

In the past few decades, education policy in Malawi, and across southern Africa, has shifted towards a learner-centered, inquiry-based model (Chisholm and Leyendecker, 2009; Mizrachi, Padilla and Susuwele-Banda, 2010). The syllabus emphasizes the importance of appealing to student interests, student-led learning, and ICT skills. Indeed, at the outset, the Malawian educators involved in this study were enthusiastic about the prospect of broad information access for students. However, in some settings, policymakers, educators and parents might view this prospect as harmful, especially because 7 percent of browsing time was spent on topics related to sex and sexuality. Access to wide ranging and accurate information is not at odds with the goals set out in the *UNESCO Ministerial Commitment on Comprehensive Sexuality Education and Sexual and Reproductive Health Services for Adolescents and Young People in Eastern and Southern Africa*, which has been signed by at least 20 countries, including Malawi. This type of commitment may increase the willingness of schools to allow access to online information. Nevertheless, schools might wish to further restrict content. Too many restrictions might result in an intervention that no longer engages students. While teachers have been widely supportive of the shift to learner-centered education, it is difficult for teachers to implement effectively in large classrooms (Altinyelken and Hoeksma, 2021). This makes the internet an attractive option, if student engagement can be maintained.

Given the pace of internet adoption, we faced a tradeoff between clear experimental design and broad external validity. We chose to implement our experiment in boarding

schools as opposed to day schools because they provided a unique, controlled environment. This allowed us to measure the impact of restricted access to online information and explore mechanisms which are likely relevant more broadly. The setting is also policy relevant; in many low-income countries, boarding schools constitute the majority, or a large minority, of public secondary schools.[56,57] If internet sessions were supervised by teachers, or further restricted by topic, we might even expect students to spend more time on school subjects. Whether this leads to a larger impact on exam scores is a subject for future research.

Providing students with internet access restricted to Wikipedia serves as an appropriate introduction to online information, and might affect the way young people use the internet more broadly. After graduation, many of the students in this study will have access to the internet on a regular basis. In future research, it will be important to measure the long run effects of this intervention on internet use and the ability to find accurate and trustworthy information online.

# References

**Abadie, Alberto, Susan Athey, Guido W. Imbens, and Jeffrey Wooldridge.** 2017. "When Should You Adjust Standard Errors for Clustering?" National Bureau of Economic Research Working Paper 24003.

**Abeberese, Ama Baafra, Todd J. Kumler, and Leigh L. Linden.** 2014. "Improving Reading Skills by Encouraging Children to Read in School: A Randomized Evaluation of

[56]For example, in Rwanda, Uganda and Tanzania, the majority of public secondary schools are boarding schools (Verspoor, 2008). In Malawi, approximately 12 percent of public secondary school students attend boarding schools (Ministry of Education Science and Technology, 2013). We argue that the internet is an effective reading resource because students find it engaging. However, we must be cautious in extrapolating our findings to day schools. Day school students might not stay after school to browse the restricted internet, especially if the unrestricted internet is available at home. In order to foster the same level of student engagement, day schools might offer restricted internet access as part of the required school day or as a formal after school program, and must be capable of restricting broader internet access.

[57]Interventions offered outside of class time can be very effective, even in day schools (Muralidharan, Singh and Ganimian, 2019).

the Sa Aklat Sisikat Reading Program in the Philippines." *Journal of Human Resources*, 49(3): 611–633.

**Allcott, Hunt, and Matthew Gentzkow.** 2017. "Social Media and Fake News in the 2016 Election." *Journal of Economic Perspectives*, 31(2): 211–36.

**Altinyelken, Hülya Kosar, and Mark Hoeksma.** 2021. "Improving Educational Quality Through Active Learning: Perspectives from Secondary School Teachers in Malawi." *Research in Comparative and International Education*, 16(2): 117–139.

**Anderson, Michael L.** 2008. "Multiple Inference and Gender Differences in the Effects of Early Intervention: A Reevaluation of the Abecedarian, Perry Preschool, and Early Training Projects." *Journal of the American Statistical Association*, 103(484): 1481–1495.

**Bailard, Catie Snow.** 2012. "A Field Experiment on the Internet's Effect in an African Election: Savvier Citizens, Disaffected Voters, or Both?" *Journal of Communication*, 62(2): 330–344.

**Bai, Yu, Di Mo, Linxiu Zhang, Matthew Boswell, and Scott Rozelle.** 2016. "The Impact of Integrating ICT with Teaching: Evidence from a Randomized Controlled Trial in Rural Schools in China." *Computers & Education*, 96: 1–14.

**Bando, Rosangela, Francisco Gallego, Paul Gertler, and Dario Romero Fonseca.** 2017. "Books or Laptops? The Effect of Shifting from Printed to Digital Delivery of Educational Content on Learning." *Economics of Education Review*, 61: 162 – 173.

**Banerjee, Abhijit, Paul Glewwe, Shawn Powers, and Melanie Wasserman.** 2013. "Expanding Access and Increasing Student Learning in Post-Primary Education in Developing Countries: A Review of the Evidence." Abdul Latif Jameel Poverty Action Lab Working Paper.

**Banerjee, Abhijit V., Shawn Cole, Esther Duflo, and Leigh L. Linden.** 2007. "Remedying Education: Evidence from Two Randomized Experiments in India." *The Quarterly Journal of Economics*, 122(3): 1235–1264.

**Barrera-Osorio, Felipe, and Leigh L. Linden.** 2009. "The Use and Misuse of Computers in Education: Evidence from a Randomized Experiment in Colombia." The World Bank Policy Research Working Paper 4836.

**Barro, Robert J., and Jong Wha Lee.** 2013. "A New Data Set of Educational Attainment in the World, 1950–2010." *Journal of Development Economics*, 104: 184–198.

**Barrow, Lisa, Lisa Markman, and Cecilia Elena Rouse.** 2009. "Technology's Edge: The Educational Benefits of Computer-Aided Instruction." *American Economic Journal: Economic Policy*, 1(1): 52–74.

**Batzilis, Dimitrios, Taryn Dinkelman, Emily Oster, Rebecca Thornton, and Deric Zanera.** 2010. "New Cellular Networks in Malawi: Correlates of Service Rollout and Network Performance." National Bureau of Economic Research Working Paper 16616.

**Beg, Sabrin, Adrienne Lucas, Waqas Halim, and Umar Saif.** Forthcoming. "Engaging Teachers with Technology Increased Achievement, Bypassing Teachers Did Not." *American Economic Journal: Economic Policy*.

**Benjamini, Yoav, Abba M. Krieger, and Daniel Yekutieli.** 2006. "Adaptive Linear Step-up Procedures that Control the False Discovery Rate." *Biometrika*, 93(3): 491–507.

**Beuermann, Diether W., Julian Cristia, Santiago Cueto, Ofer Malamud, and Yyannu Cruz-Aguayo.** 2015. "One Laptop per Child at Home: Short-Term Impacts from a Randomized Experiment in Peru." *American Economic Journal: Applied Economics*, 7(2): 53–80.

**Biesta, Gert.** 2007. "Why "What Works" Won't Work: Evidence-based Practice and the Democratic Deficit in Educational Research." *Educational Theory*, 57(1): 1–22.

**Borkum, Evan, Fang He, and Leigh L. Linden.** 2012. "The Effects of School Libraries on Language Skills: Evidence from a Randomized Controlled Trial in India." National Bureau of Economic Research Working Paper 18183.

**Bruhn, Miriam, and David McKenzie.** 2009. "In Pursuit of Balance: Randomization in Practice in Development Field Experiments." *American Economic Journal: Applied Economics*, 1(4): 200–232.

**Bruner, Jerome S.** 1961. "The Act of Discovery." *Harvard Educational Review*, 31: 21–32.

**Brunette, Tracy, Benjamin Piper, Rachel Jordan, Simon King, and Rehemah Nabacwa.** 2019. "The Impact of Mother Tongue Reading Instruction in Twelve Ugandan Languages and the Role of Language Complexity, Socioeconomic Factors, and Program Implementation." *Comparative Education Review*, 63(4): 591–612.

**Bulman, George, and Robert W. Fairlie.** 2016. "Technology and Education: Computers, Software, and the Internet." In *Handbook of the Economics of Education*. Vol. 5, 239–280. Elsevier.

**Buys, Piet, Susmita Dasgupta, Timothy S. Thomas, and David Wheeler.** 2009. "Determinants of a Digital Divide in Sub-Saharan Africa: A Spatial Econometric Analysis of Cell Phone Coverage." *World Development*, 37(9): 1494–1505.

**Campante, Filipe, Ruben Durante, and Francesco Sobbrio.** 2018. "Politics 2.0: The Multifaceted Effect of Broadband Internet on Political Participation." *Journal of the European Economic Association*, 16(4): 1094–1136.

**Carrillo, Paul E., Mercedes Onofa, and Juan Ponce.** 2011. "Information Technology and Student Achievement: Evidence from a Randomized Experiment in Ecuador." Inter-American Development Bank Working Paper IDB-WP-223.

**Chen, Yan, Rosta Farzan, Robert E. Kraut, Iman YeckehZaare, and Ark Fangzhou Zhang.** 2020. "Motivating Experts to Contribute to Digital Public Goods: A Personalized Field Experiment on Wikipedia." Working Paper.

**Chen, Yuyu, and David Y. Yang.** 2019. "The Impact of Media Censorship: 1984 or Brave New World?" *American Economic Review*, 109(6): 2294–2332.

**Chisholm, Linda, and Ramon Leyendecker.** 2009. "Curriculum Reform in Sub-Saharan Africa: When Local Meets Global." In *International Handbook of Comparative Education*. 685–702. Springer.

**Chung, Chung Joo, Yoonjae Nam, and Michael A. Stefanone.** 2012. "Exploring Online News Credibility: The Relative Influence of Traditional and Technological Factors." *Journal of Computer-Mediated Communication*, 17(2): 171–186.

**Cristia, Julian, Pablo Ibarrarán, Santiago Cueto, Ana Santiago, and Eugenio Severín.** 2017. "Technology and Child Development: Evidence from the One Laptop per Child Program." *American Economic Journal: Applied Economics*, 9(3): 295–320.

**de Hoop, Jabobus.** 2010. "Selective Secondary Education and School Participation in Sub-Saharan Africa: Evidence from Malawi." Tinbergen Institute Discussion Paper 10-041/2.

**Derksen, Laura, Adamson Muula, and Joep van Oosterhout.** 2021. "Love in the Time of HIV: How Beliefs about Externalities Impact Health Behavior." Working Paper.

**Dewey, John.** 1938. *Logic: The Theory of Inquiry.* Holt.

**Dupas, Pascaline.** 2011. "Do Teenagers Respond to HIV Risk Information? Evidence from a Field Experiment in Kenya." *American Economic Journal: Applied Economics*, 3(1): 1–34.

**Evans, David K, and Amina Mendez Acosta.** 2020. "Education in Africa: What Are We Learning?" *Journal of African Economies*, 30(1): 13–54.

**Evans, David K, and Fei Yuan.** 2020. "How Big are Effect Sizes in International Education Studies." Center for Global Development Working Paper 545.

**Faber, Benjamin, Rosa Sanchis-Guarner, and Felix Weinhardt.** 2015. "ICT and Education: Evidence from Student Home Addresses." National Bureau of Economic Research Working Paper 21306.

**Fairlie, Robert W., and Jonathan Robinson.** 2013. "Experimental Evidence on the Effects of Home Computers on Academic Achievement Among Schoolchildren." *American Economic Journal: Applied Economics*, 5(3): 211–40.

**Falisse, Jean-Benoit, Marieke Huysentruyt, and Anders Olofsgård.** 2019. "Incentivizing Textbooks for Self-study: Experimental Evidence on Student Learning from the Democratic Republic of Congo." Working Paper.

**Freire, Paulo.** 1970. *Pedagogy of the Oppressed*. Seabury Press.

**Gallego, Francisco A, Ofer Malamud, and Cristian Pop-Eleches.** 2020. "Parental Monitoring and Children's Internet Use: The Role of Information, Control, and Cues." *Journal of Public Economics*, 188: 104208.

**Galperin, Hernan, and M. Fernanda Viecens.** 2017. "Connected for Development? Theory and Evidence about the Impact of Internet Technologies on Poverty Alleviation." *Development Policy Review*, 35(3): 315–336.

**Giles, Jim.** 2005. "Internet Encyclopaedias Go Head to Head." *Nature*, 438: 900–901.

**Giroux, Henry A.** 2020. *On Critical Pedagogy.* Bloomsbury Publishing.

**Glewwe, Paul, Michael Kremer, and Sylvie Moulin.** 2009. "Many Children Left Behind? Textbooks and Test Scores in Kenya." *American Economic Journal: Applied Economics*, 1(1): 112–35.

**Goolsbee, Austan, and Jonathan Guryan.** 2006. "The Impact of Internet Subsidies in Public Schools." *The Review of Economics and Statistics*, 88(2): 336–347.

**Head, Alison J., and Michael B. Eisenberg.** 2010. "How Today's College Students Use Wikipedia for Course-Related Research." *First Monday*, 15(3).

**He, Fang, Leigh L. Linden, and Margaret MacLeod.** 2008. "How to Teach English in India: Testing the Relative Productivity of Instruction Methods within the Pratham English Language Education Program." Abdul Latif Jameel Poverty Action Lab Working Paper.

**Heilman, James M, Eckhard Kemmann, Michael Bonert, Anwesh Chatterjee, Brent Ragar, Graham M. Beards, David J. Iberri, Matthew Harvey, Brendan Thomas, Wouter Stomp, et al.** 2011. "Wikipedia: A Key Tool for Global Public Health Promotion." *Journal of Medical Internet Research*, 13(1): e14.

**Hinnosaar, Marit.** 2019. "Gender Inequality in New Media: Evidence from Wikipedia." *Journal of Economic Behavior & Organization*, 163: 262–276.

**Hjort, Jonas, and Jonas Poulsen.** 2019. "The Arrival of Fast Internet and Employment in Africa." *American Economic Review*, 109(3): 1032–1079.

**hooks, bell.** 2010. *Teaching Critical Thinking: Practical Wisdom.* Routledge.

**Kerwin, Jason.** 2018. "Scared Straight or Scared to Death? The Effect of Risk Beliefs on Risky Behaviors." Working Paper.

**Kerwin, Jason T., and Rebecca L. Thornton.** 2021. "Making the Grade: The Sensitivity of Education Program Effectiveness to Input Choices and Outcome Measures." *The Review of Economics and Statistics*, 103(2): 251–264.

**Kho, Kevin, Leah Lakdawala, and Eduardo Nakasone.** 2020. "Dynamic Impacts of School-based Internet Access on Student Learning." Working Paper.

**Knauer, Heather A., Pamela Jakiela, Owen Ozier, Frances Aboud, and Lia C. H. Fernald.** 2020. "Enhancing Young Children's Language Acquisition through Parent–Child Book-Sharing: A Randomized Trial in Rural Kenya." *Early Childhood Research Quarterly*, 50: 179–190.

**Lazer, David MJ, Matthew A. Baum, Yochai Benkler, Adam J. Berinsky, Kelly M. Greenhill, Filippo Menczer, Miriam J. Metzger, Brendan Nyhan, Gordon Pennycook, David Rothschild, et al.** 2018. "The Science of Fake News." *Science*, 359(6380): 1094–1096.

**Lee, David S.** 2009. "Training, Wages, and Sample Selection: Estimating Sharp Bounds on Treatment Effects." *The Review of Economic Studies*, 76(3): 1071–1102.

**Lih, Andrew.** 2004. "Wikipedia as Participatory Journalism: Reliable Sources? Metrics for Evaluating Collaborative Media as a News Resource." *Nature*, 3(1): 1–31.

**Likupe, Gloria, Jesman Chintsanya, Monica Magadi, Alister Munthali, and Medison Makwemba.** 2021. "Barriers to Sexual and Reproductive Education Among In-school Adolescents in Zomba and Mangochi Districts, Malawi." *Sex Education*, 21(4): 450–462.

**Lim, Sook.** 2009. "How and Why do College Students Use Wikipedia?" *Journal of the American Society for Information Science and Technology*, 60(11): 2189–2202.

**Linden, Leigh L.** 2008. "Complement or Substitute?: The Effect of Technology on Student Achievement in India." Abdul Latif Jameel Poverty Action Lab Working Paper.

**Lucas, Adrienne M., Patrick J. McEwan, Moses Ngware, and Moses Oketch.** 2014. "Improving Early-Grade Literacy in East Africa: Experimental Evidence from Kenya and Uganda." *Journal of Policy Analysis and Management*, 33(4): 950–976.

**Machin, Stephen, and Sandra McNally.** 2008. "The Literacy Hour." *Journal of Public Economics*, 92(5): 1441–1462.

**MacMillan, Margy, and Allison MacKenzie.** 2012. "Strategies for Integrating Information Literacy and Academic Literacy: Helping Undergraduate Students Make the Most of Scholarly Articles." *Library Management*, 33(9): 525–535.

**Malamud, Ofer.** 2019. "The Effect of Home Computers and the Internet on Children's Human Capital Development." *DICE Report*, 17(2): 34–40.

**Malamud, Ofer, and Cristian Pop-Eleches.** 2011. "Home Computer Use and the Development of Human Capital." *The Quarterly Journal of Economics*, 126(2): 987–1027.

**Malamud, Ofer, Santiago Cueto, Julian Cristia, and Diether W. Beuermann.** 2019. "Do Children Benefit from Internet Access? Experimental Evidence from Peru." *Journal of Development Economics*, 138: 41–56.

**McEwan, Patrick J.** 2015. "Improving Learning in Primary Schools of Developing Countries: A Meta-Analysis of Randomized Experiments." *Review of Educational Research*, 85(3): 353–394.

**McLaren, Peter.** 2015. *Life in Schools: An Introduction to Critical Pedagogy in the Foundations of Education.* Routledge.

**Mesgari, Mostafa, Chitu Okoli, Mohamad Mehdi, Finn Arup Nielsen, and Arto Lanamaki.** 2015. ""The Sum of All Human Knowledge": A Systematic Review of Scholarly Research on the Content of Wikipedia." *Journal of the Association for Information Science and Technology*, 66(2): 219–245.

**Miguel, Edward, and Michael Kremer.** 2004. "Worms: Identifying Impacts on Education and Health in the Presence of Treatment Externalities." *Econometrica*, 72(1): 159–217.

**Miner, Luke.** 2015. "The Unintended Consequences of Internet Diffusion: Evidence from Malaysia." *Journal of Public Economics*, 132: 66–78.

**Ministry of Education Science and Technology.** 2013. "Education Management Information System, Education Statistics 2013." Ministry of Education Science and Technology.

**Mizrachi, Adela, Olivia Padilla, and William Susuwele-Banda.** 2010. "Active-Learning Pedagogies as a Reform Initiative: The Case of Malawi." American Institute for Research: USAID.

**Mo, Di, Johan Swinnen, Linxiu Zhang, Hongmei Yi, Qinghe Qu, Matthew Boswell, and Scott Rozelle.** 2013. "Can One Laptop per Child Reduce the Digital Divide and Educational Gap? Evidence from a Randomized Experiment in Migrant Schools in Beijing." *World Development*, 46: 14–29.

**Muralidharan, Karthik, Abhijeet Singh, and Alejandro J. Ganimian.** 2019. "Disrupting Education? Experimental Evidence on Technology-Aided Instruction in India." *American Economic Review*, 109(4): 1426–1460.

**National Statistical Office (Malawi), and ICF.** 2017. "Malawi Demographic and Health Survey 2015-16." National Statistical Office and ICF.

**Ozier, Owen.** 2018. "The Impact of Secondary Schooling in Kenya: A Regression Discontinuity Analysis." *Journal of Human Resources*, 53(1): 157–188.

**Piper, Benjamin, Stephanie Simmons Zuilkowski, Margaret Dubeck, Evelyn Jepkemei, and Simon J. King.** 2018. "Identifying the Essential Ingredients to Literacy and

Numeracy Improvement: Teacher Professional Development and Coaching, Student Textbooks, and Structured Teachers' Guides." *World Development*, 106: 324 – 336.

**Rancière, Jacques.** 1991. *The Ignorant Schoolmaster.* Vol. 1, Stanford University Press Stanford, CA.

**Rodriguez-Segura, Daniel.** 2021. "EdTech in Developing Countries: A Review of the Evidence." *The World Bank Research Observer*.

**Rosenzweig, Roy.** 2006. "Can History be Open Source? Wikipedia and the Future of the Past." *The Journal of American History*, 93(1): 117–146.

**Sabarwal, Shwetlena, David K. Evans, and Anastasia Marshak.** 2014. "The Permanent Input Hypothesis: The Case of Textbooks and (No) Student Learning in Sierra Leone." The World Bank Policy Research Working Papers 7021.

**Verspoor, Adriaan.** 2008. *At the Crossroads: Choices for Secondary Education in Sub-Saharan Africa.* World Bank Publications.

**Vigdor, Jacob L., Helen F. Ladd, and Erika Martinez.** 2014. "Scaling the Digital Divide: Home Computer Technology and Student Achievement." *Economic Inquiry*, 52(3): 1103–1119.

**Yanguas, Maria Lucia.** 2020. "Technology and Educational Choices: Evidence from a One-Laptop-per-Child Program." *Economics of Education Review*, 76: 101984.

# Restricted Access: How the Internet Can Be Used to Promote Reading and Learning

Laura Derksen, Catherine Michaud-Leclerc and Pedro CL Souza

# Appendices

# For Online Publication

## Appendix A Topic Classifications and Browsing

In this section, we discuss our method of classifying student browsing behavior in terms of topic or school subject, as well as potential alternatives. We also conduct additional robustness checks related to our description of browsing behavior.

As explained in Section 3.2, we use the Wikipedia category tree to assign each page to a broad topic. The Wikipedia category tree is user-generated and user-maintained, and contains both long paths and loops. In order to feasibly generate a unique topic classification, we consider every path in the Wikipedia category tree that reaches the top of the tree in at most six steps, and we ignore paths that veer away from the top category one level below. We select the top-level category (see https://en.wikipedia.org/wiki/Category:

Main_topic_classifications) with the highest number of paths. See Table S2 in the supplementary materials for a random sample of pages and topic classifications.

Classifying pages related to sex and sexuality is more complicated, as there is no appropriate top-level category. However, Wikipedia does have subcategories for "Human Reproduction", "Human Sexuality", "Sexual Health", and "Sexuality and Society", which we refer to as "sex-related" subcategories. Again, each Wikipedia page has multiple paths through the category tree. Including all paths that contain any sex-related subcategory is likely too broad, and will include many pages that are better classified as "Entertainment" (for example, pages for musicians, actors, films, and songs often have some paths that pass through sex-related subcategories.) We therefore select a threshold, classifying a page as sex-related if 10 percent of paths contain a sex-related subcategory. Above this threshold, most pages appear to be primarily sex-related. With a less conservative threshold of 5 percent, some pages appear to be primarily sex-related. See Table S3 in the supplementary materials for a random sample of pages and classifications according to these measures. According to our preferred threshold, students spent 7 percent of their time browsing pages related to sex and sexuality. Using a less conservative threshold (5 percent of paths) would increase our estimate to 8 percent of student browsing time. Using no threshold, that is, classifying a page as sex-related if there is any path containing a sex-related subcategory, would increase our estimate to 17 percent of student browsing time.

As explained in Section 3.5, we map each topic in the school syllabus, by hand, to a specific Wikipedia page, a small set of pages, or a narrow sub-

category. We provide the entire mapping for Biology in Tables S4 and S5 in the supplementary materials, and other subject mappings are available upon request. Table S6 in the supplementary materials shows the most popular syllabus topics by hours spent browsing. Some, but not all, of the most popular topics relate to sex and sexuality, which motivates our discussion of an alternate measure that excludes these topics in Section 3.5. We also investigate a mapping that excludes topics that students spend a disproportionate amount of time browsing, compared to the average topic browsing time for a particular subject. We omit topics that are more than ten times as popular as the average topic, according to within-subject browsing time. Omitting over-represented topics, students spend only 16 percent of their time on the school syllabus. Biology remains the most popular subject (1.3 browsing hours), and is nearly twice as popular as any other subject (less than 0.8 hours).

On the other hand, our mapping may be too conservative. Students might use Wikipedia to study, broadly speaking, without adhering strictly to the school syllabus. For example, several students visited pages related to quantum mechanics, a topic that is not usually taught in secondary school physics. A less conservative mapping would include all pages under Wikipedia subcategories for the school subjects themselves. The Wikipedia category tree has subcategories corresponding to each school subject, with the exception of Social Studies, for which we use "Social Sciences", and Life Skills, for which we use "Health". Using this broader categorization, the average student spends 66 percent of their time browsing pages related to school subjects. Biology is no longer the most popular subject; by this measure the most popular subject is History, a Wikipedia subcategory that includes news events and important

historical figures.

Finally, in Section 4.2 we describe an incentivized quiz that we assigned to students between Endline A and Endline B. They were instructed to attempt to find the answers to two questions, and this instruction may have influenced their browsing behavior. Here, we conduct a robustness check in which we limit our examination of student browsing behavior to the period before Endline A began. This reduces the total number of browsing hours from 28.6 to 25.1. The proportion of time spent on sex-related pages (7 percent of browsing time) and syllabus-related pages (22 percent of browsing time) remain unchanged.

# Appendix B Classification of News Events

In Section 3.3 and Figure 3, we show that students browse pages related to the news, and focus mainly on events in Africa rather than elsewhere. Here, we explain precisely how the classification of pages associated to news events is accomplished. The starting point is two Wikipedia pages for significant news events in 2017 and 2018, `https://en.wikipedia.org/wiki/2017` and `https://en.wikipedia.org/wiki/2018`. These pages are, like all Wikipedia pages, written and maintained by users, and events in Africa may be underrepresented. We filter the pages for events that occurred during our experimental window – from November 2nd, 2017 – to events prior to May 11th, 2018, when Endline A began; this survey included instructions to search for a particular news event, which may have affected news browsing behavior.[1]

[1]Results are virtually unchanged including post-May 11th news events.

The next step is to associate event descriptions to specific Wikipedia pages, so that we can look for evidence of browsing in our data. We do so methodically by identifying a set of event-related Wikipedia pages for each event. We start from the set of Wikipedia pages that appear as hyperlinks within the Wikipedia event description. For example, the event on November 2nd, 2017 is described in Wikipedia as

> "A new species of orangutan is identified in Indonesia, becoming the third known species of orangutan as well as the first great ape to be described for almost a century."

where the underlined words represent hyperlinks to the following Wikipedia pages:

$\mathcal{S}^*$ = {`https://en.wikipedia.org/wiki/Tapanuli_orangutan`,
`https://en.wikipedia.org/wiki/Indonesia`,
`https://en.wikipedia.org/wiki/Orangutan`,
`https://en.wikipedia.org/wiki/Hominidae`}.

We extract the title of each Wikipedia page (which coincides with the words after the root website address `https://en.wikipedia.org/wiki/`) and obtain, respectively,

$\mathcal{S}$ = {`Tapanuli Orangutan`, `Indonesia`, `Orangutan`, `Hominidae`}.

We then search our data for the time (in minutes) and number of students that browsed any Wikipedia page with a title containing any element in $\mathcal{S}$. For instance, in this case we include the Wikipedia page title `Sumatran Orangutan` as it contains the term `Orangutan`. This process ensures that we capture pages

related to the event but not necessarily linked to Wikipedia's own event description. We then hand-classify the events that physically occurred in Africa, or that directly concern African states or politicians.

We devised this procedure for two reasons. First, it leverages Wikipedia-generated content to directly link pages to events. Second, it ensures that the classification is not driven by experimenter effects, reduces subjective judgements, and can be replicated across all events in our database.

# Appendix C Preference for Wikipedia

Early access to Wikipedia might affect the way that young people search for online information and trust its accuracy. Most students will gain access to the broader internet after graduating. Exposure to Wikipedia through the intervention may influence internet preferences and future internet use.

In Section 4, we showed that treatment students became more comfortable with information technology, and learned to use it to quickly find accurate information. Here, we estimate the same specification (Equation 1) to show that students find Wikipedia to be an easy to use and reliable source of information, and develop a preference for it over other online sources.

First, we show that treatment students are more likely than control students to understand what Wikipedia is and how it can be used. In Endline A, we ask students whether they believe it is possible to find information about world events on Wikipedia, to find student exam scores, to watch movies, and to communicate with friends. We also ask students to identify several logos for internet applications, and note whether they correctly name the Wikipedia

logo. We construct a summary index[2] based on correct answers to these five questions. Column 1 of Appendix Table A4 shows that relative to the control group, treatment students have a significantly better understanding of Wikipedia ($0.88\sigma$).

Next, we ask whether students prefer Wikipedia to other parts of the internet, for which types of information, and why. Half of the students in our sample do have past experience with the internet, and the others likely have preconceived notions about it. For the latter, we interpret stated preferences relative to these preconceived notions.

Using survey results from Endline B, we show that students in the treatment group are more likely to prefer Wikipedia for information about safe sex and the news (Columns 2 and 3 of Appendix Table A4). A majority of treatment group students prefer Wikipedia to the internet for these two topics. Indeed, we saw in Section 3 that students did often search for both of these topics. This preference for Wikipedia appears for both students with and without past internet experience, and for high and low achievers. However, when we consider news information, the Wikipedia preference is smaller and insignificant for high achievers and for students with past internet experience. This suggests that the intervention may not shift students away from online news sources altogether.

We find that treatment group students are more likely to find information

[2]We are again guided by Anderson (2008) in our construction of a summary index. For each outcome in the index, we standardize by subtracting the mean and dividing by the control group standard deviation. For each student, the index variable is a weighted mean of these standardized outcomes. The weights are determined by the inverse of the covariance matrix for the standardized outcomes. This procedure gives less weight to highly correlated outcomes and outcomes with many missing values.

on Wikipedia trustworthy, easy to understand and easy to find as compared to information on the internet (Columns 4 to 6). Again, these effects appear for both students with and without past internet experience, and for both low and high achievers. Within the treatment group, a large majority prefer Wikipedia to the internet along each of the three dimensions.

# Appendix D Spillovers

While control students did not gain direct access to Wikipedia or the internet during the experiment, our primary outcomes may still be subject to spillovers. For example, a student's language skills or Biology knowledge may improve if they study with students who have benefited from Wikipedia access.

To test for this type of positive spillover on academic performance, we use baseline social network data. At baseline, we ask every student to name the friends they study with. We say there is a study link between two students if either student names the other. While social networks change over the course of a school year, study friends are in part determined by school-level decisions such as classroom, dormitory, and formal study groups. These formal study groups are assigned by teachers at the start of the school year, and meet regularly. Therefore, study friends are more likely to remain constant over the school year. Study friends are also most likely to benefit from spillovers that impact academic performance.

Similar to Miguel and Kremer (2004), we estimate Equation 2 and the heterogeneous treatment effects by baseline achievement from Section 5, adding

controls for the number of study friends total and the number of study friends in the treatment group. We also interact own treatment status with the number of treated study friends, as spillovers may exist only between treatment and control group students.

We find positive, insignificant spillovers from the treatment group to the control group (see Table A7, which reports results for term 3 English and Biology). In this specification, our estimated effect sizes are slightly larger ($0.18\sigma$ and $0.15\sigma$ for English and Biology, respectively), but have larger standard errors. Effects for low achievers are also larger, and remain significant.

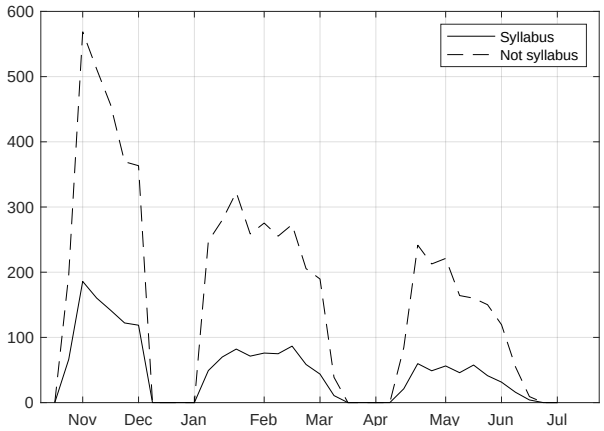
This specification may not capture all spillovers, as positive spillovers may exist beyond study friends at baseline. Moreover, exam scores could be subject to negative spillovers, either due to demotivation, or due to grading on a curve, as discussed in Section 6.1. However, based on standard measures from the Oxford Happiness Questionnaire, we find that while control students are more likely to view the intervention as unfair (22 percent versus 9 percent, Column 6 of Appendix Table A2), they do not score lower on other measures of ambition, confidence or happiness (Columns 1 to 5 of Appendix Table A2), and low achievers in the control group do not appear to be worse affected than high achievers. Appendix Figure A5 plots the distribution of raw exam scores for English and Biology by form, school year, and treatment.[3] If teachers were constrained by a grading curve, we would expect control students to receive lower scores compared to the previous cohort, to compensate for the higher scores among treated students. We do not see evidence of such a

[3]We cannot compute this distribution for the previous cohort of Form 4 students, as they are outside our sample.

pattern. Overall, the distribution of exam scores, and its median, shifts to the right for both treatment and control students in all four panels. This suggests that our results are not likely due to a decrease in exam scores for control students. Given the small, positive spillovers we observe between study friends, it appears that overall spillovers are likely to be positive from treatment to control students, and that our estimates slightly underestimate the true impact of the intervention on learning.

# Appendix Figures and Tables

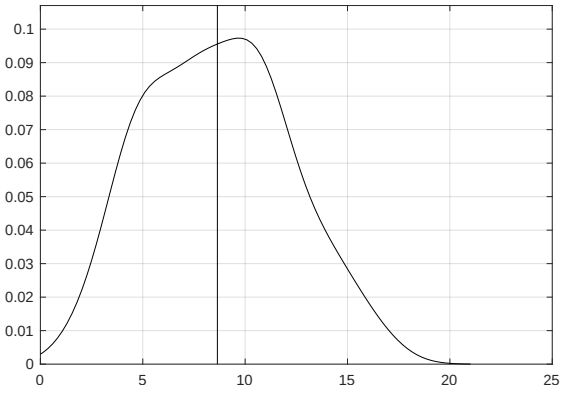
Appendix Figure A1: Weekly Hours Spent on Browsing in Total and on School Subjects Over Time



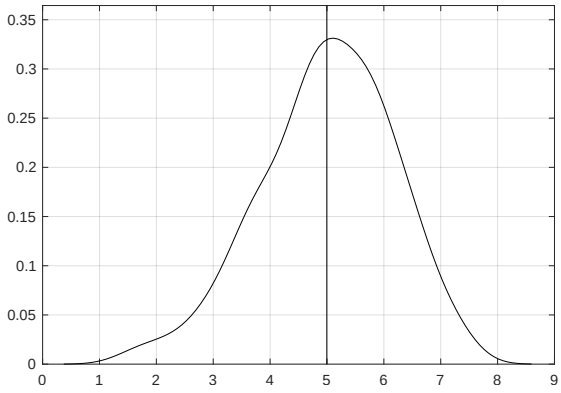

*Notes:* Weekly browsing hours on syllabus- and non syllabus-related Wikipedia pages. The digital library was open for 20-22 weeks, from November 2017 to June 2018, excluding Christmas and Easter vacations.

Appendix Figure A2: Diversity of browsing pattern across students

Panel A. Diversity of topics

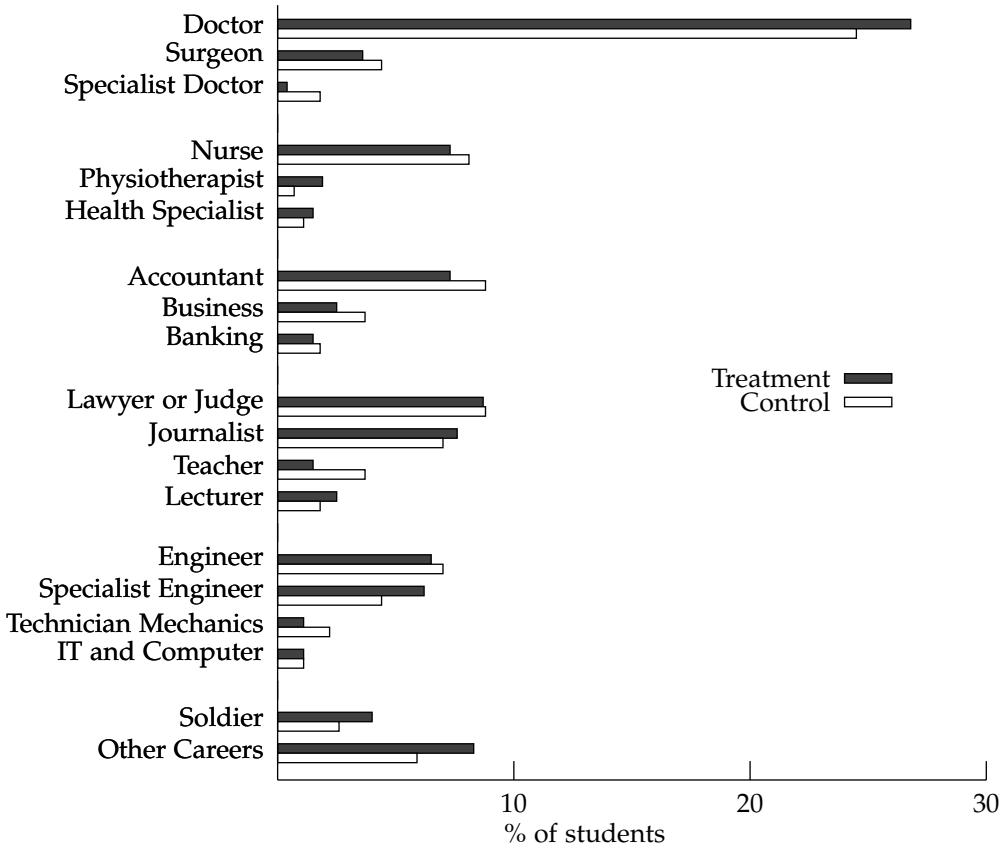



Panel B. Diversity of subjects



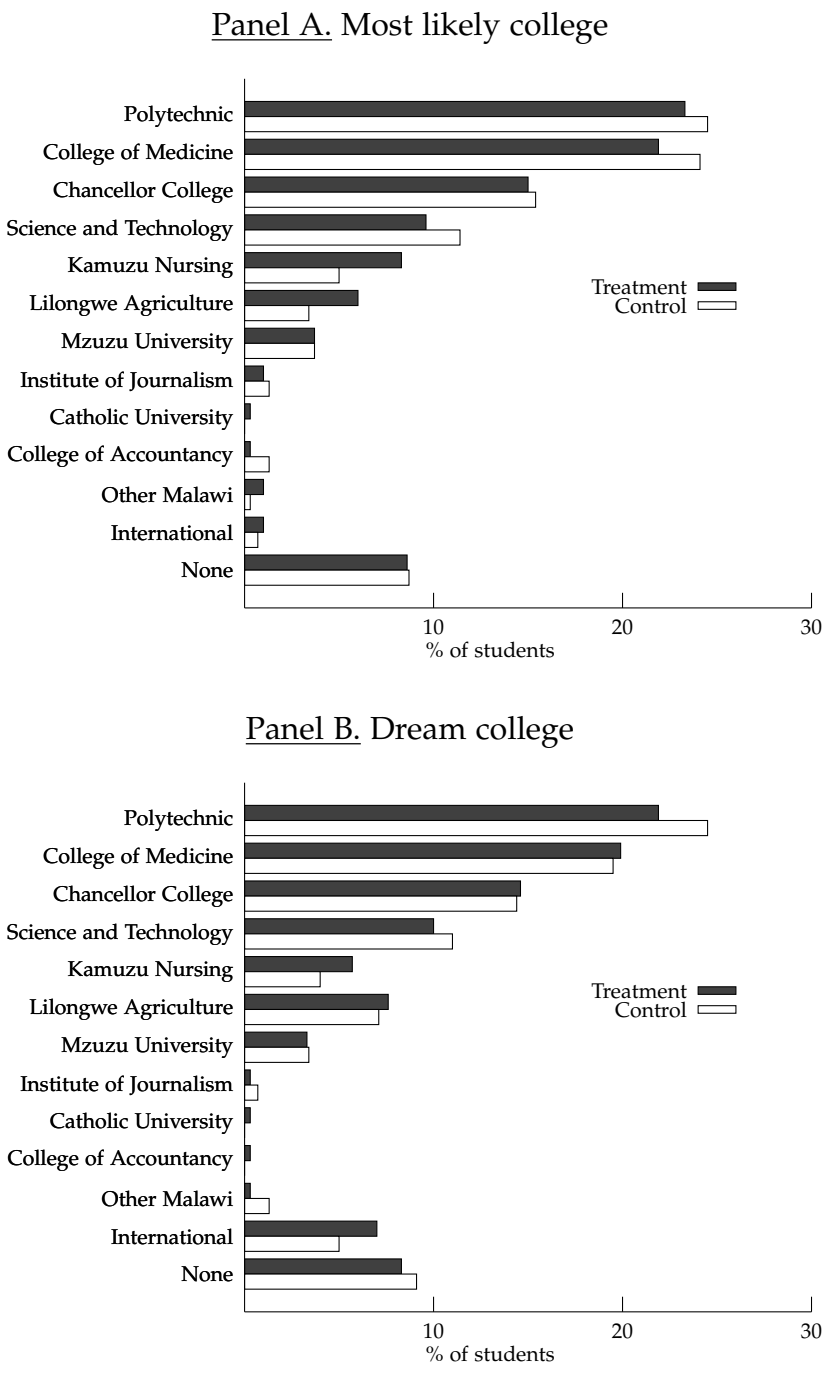

*Notes:* Panel A: Diversity of browsing topics across students. Adaptation of the Herfindahl index, computed as $d_i = 1/\sum_j s_{ij}^2$ where $s_{ij}$ is the share of time that student $i$ spends in topic $j$, throughout the duration of the experiment. Larger numbers represent broader diversity of topics. Dashed line is the average (8.64 topics). Panel B: Diversity of browsing hours per school subject across students, aggregated over the course of one academic year. Similar adaptation of the Herfindahl index. Dashed line is the average (5.00 subjects).

Appendix Figure A3: Career Plans at Endline



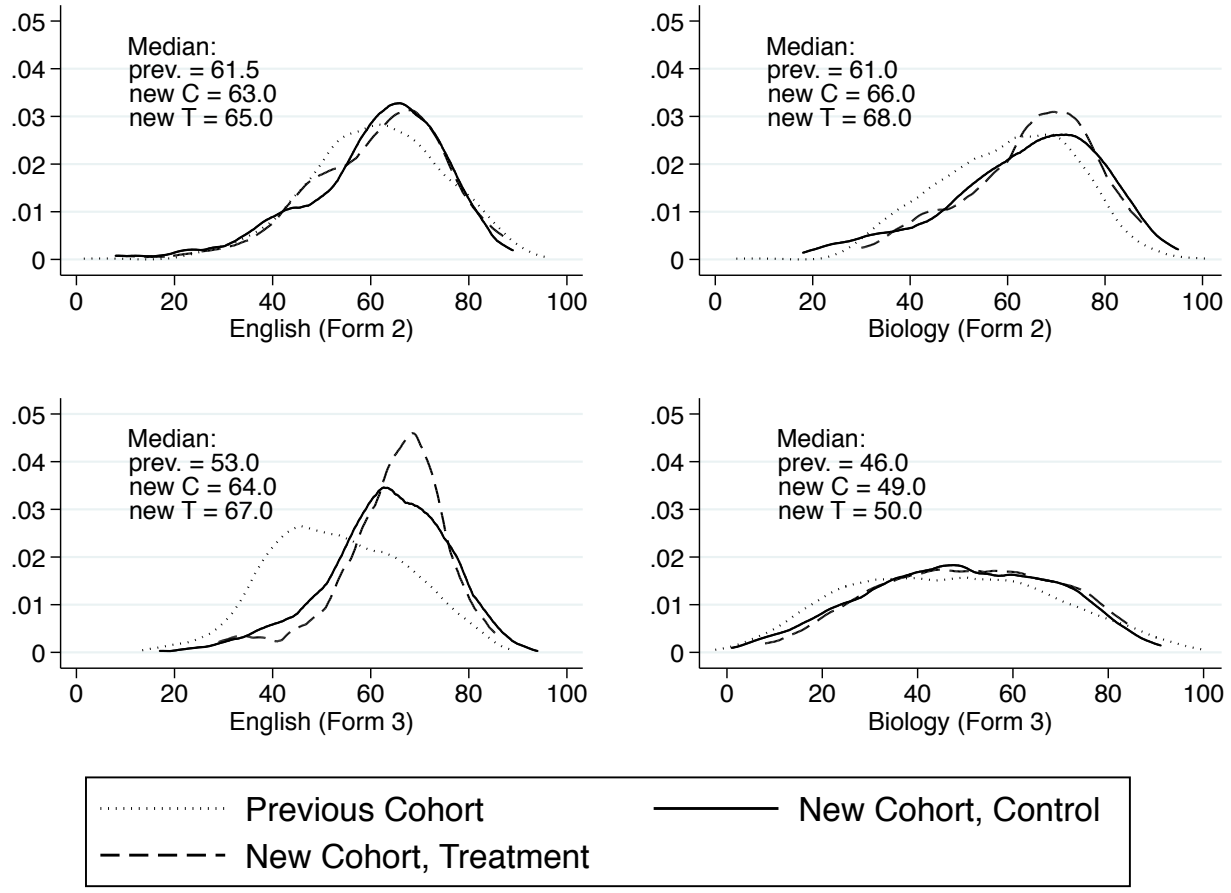

*Notes:* Frequency of career choices at endline. The sample is students in the treatment group and in the subsample of the control group with supplementary surveys.

Appendix Figure A4: College Choice at Endline




*Notes:* Frequency of most likely and dream college in Panels A and B, respectively, at endline. The sample is students in the treatment group and in the subsample of the control group with supplementary surveys.

Appendix Figure A5: Exam Scores Distribution




*Notes:* Raw exam scores of Form 2 and Form 3 students in English and Biology. The dotted lines are the distributions of exam scores of the previous cohort (enrolled in Forms 2 and 3 in the school year prior to the intervention, 2016-17). The continuous and dashed lines are the distributions of exam scores of the new cohort (enrolled in Forms 2 and 3 in the school year of the intervention, 2017-18), for control and treatment students respectively. At top left of each graph, we report the median scores of the previous cohorts, and the median scores of the new cohorts by treatment status.

## Appendix Table A1: Mobile Phone and Internet Use

| | % population within network coverage | Mobile subscriptions per 100 inh. | | Internet bundle price as % of income | | % population with internet use | | GDP per capita |
|---|---|---|---|---|---|---|---|---|
| | 2006 | 2014 | 2017 | 2007 | 2017 | 2007 | 2017 | 2017 |
| Malawi | 93.1 | 7.6 | 41.7 | 45.2 | 18.0 | 1.0 | 13.8 | $339 |
| Zambia | 44.9 | 20.7 | 78.6 | 15.2 | 12.6 | 4.9 | 27.9 | $1,332 |
| Mozambique | 42.1 | 13.9 | 40.0 | 13.3 | 7.2 | .9 | 20.8 | $4412 |
| South Africa | 99.8 | 84.8 | 156.0 | 1.3 | 1.2 | 8.1 | 56.2 | $6,340 |
| LDC | – | 15.1 | 68.6 | 21.4 | 14.8 | 1.9 | 17.8 | $1,093 |
| Developing | – | 39.1 | 99.0 | 9.0 | 6.3 | 11.8 | 42.3 | $5,229 |
| Developed | – | 102.0 | 127.0 | .9 | .8 | 59.1 | 79.5 | $42,346 |
| World | – | 50.6 | 103.6 | 6.5 | 4.6 | 20.5 | 48.6 | $10,749 |

*Notes*: "% population with GMS coverage" from Buys et al. (2009). Remaining data, excluding GDP per capita, from the International Telecommunications Unit. Classification of "Least Developed Country" (LDC), "developing" and "developed countries" also drawn from the International Telecommunications Unit. "Internet bundle price as % of income" is the proportion of the average national income to purchase 1GB of a data bundle, monthly. GDP per capita obtained from the World Bank. Definition of LDC in the last column uses the United Nations' classification. Average GDP per capita of developing (developed) countries approximated by the average GDP per capita of middle (upper) income countries. Income in current US$.

Appendix Table A2: Happiness, Demotivation, and Fairness

| | (1) Ambitious | (2) World Good Place | (3) Life Rewarding | (4) Take Anything On | (5) Joy and Elation | (6) Fair |
|---|---|---|---|---|---|---|
| Panel A. Overall effects | | | | | | |
| Control | .113 | -.049 | -.055 | -.028 | .054 | -.129*** |
| | (.080) | (.100) | (.078) | (.075) | (.072) | (.030) |
| | p = .273 | p = .715 | p = .588 | p = .774 | p = .573 | p = .001 |
| Panel B. Heterogeneous treatment effects | | | | | | |
| Control × low achiever | .012 | .081 | -.111 | .044 | .123 | -.096** |
| | (.110) | (.136) | (.103) | (.105) | (.096) | (.042) |
| | p = .927 | p = .647 | p = .412 | p = .743 | p = .337 | p = .079 |
| Control × high achiever | .221* | -.191 | .007 | -.105 | -.020 | -.165*** |
| | (.116) | (.148) | (.119) | (.107) | (.106) | (.042) |
| | p = .142 | p = .331 | p = .968 | p = .447 | p = .889 | p = .003 |
| Mean of dependent variable in treatment | 4.130 | 3.615 | 4.073 | 4.225 | 4.138 | .912 |
| Strata FE | yes | yes | yes | yes | yes | yes |
| Number of students | 547 | 514 | 548 | 549 | 548 | 547 |

*Notes:* Treatment effects on measures of happiness and fairness. (1) to (5) are indicators for whether, at endline, the student agrees with the following statements: (1) "I am more ambitious than most people", (2) "I think that the world is a good place", (3) "I feel that life is very rewarding", (4) "I feel able to take anything on", and (5) "I often experience joy and elation". (6) is an indicator that equals 1 if the student agrees that the intervention was fair or totally fair. High (low) achievers defined as above (below) median exam scores at the baseline. We include a control for baseline measure in (1) to (5), and all regressions include strata fixed effects. Randomization was stratified by school, form, above median achievement and past internet use. Robust standard errors in parentheses. * p<0.10, ** p<0.05, *** p<0.01. Randomization inference p-values based on 10,000 replications denoted as "p =".

Appendix Table A3: Balance Table on Stratification Variables

| | (1) Treatment | (2) Control (subsample) | (3) $p$-value | (4) Control (full) | (5) $p$-value |
|---|---|---|---|---|---|
| School 1 | .272 | .262 | .768 | .261 | .689 |
| | (.446) | (.440) | | (.439) | |
| School 2 | .262 | .289 | .475 | .280 | .537 |
| | (.441) | (.454) | | (.449) | |
| School 3 | .236 | .232 | .900 | .229 | .792 |
| | (.425) | (.423) | | (.420) | |
| School 4 | .229 | .218 | .745 | .230 | .968 |
| | (.421) | (.414) | | (.421) | |
| Form 2 | .342 | .346 | .929 | .342 | .999 |
| | (.475) | (.476) | | (.475) | |
| Form 3 | .332 | .329 | .930 | .328 | .892 |
| | (.472) | (.471) | | (.470) | |
| Form 4 | .326 | .326 | .998 | .330 | .891 |
| | (.469) | (.469) | | (.470) | |
| Above median Bio. and Eng. exam scores | .468 | .473 | .908 | .472 | .906 |
| | (.500) | (.500) | | (.499) | |
| Past internet use | .502 | .500 | .968 | .505 | .908 |
| | (.501) | (.501) | | (.500) | |
| Number of students | 301 | 298 | | 1,207 | |

*Notes:* Balance table across the treatment (N=301), subsample of control (N=298) and full sample of control (N=1,207) groups. (3) and (5) show the $p$-value of the difference between treatment and subsample of control, and treatment and full sample of control groups, respectively. "Above median Biology and English exam scores" computed based on the end of the previous school year. "Past internet use" is an indicator for whether the student had any exposure to internet prior to the experiment. Standard errors in parentheses.

# Appendix Table A4: Is Wikipedia Information Better than the Internet?

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| | | Wikipedia is better for | | How is Wikipedia better | | |
| | Understand what Wikipedia is (index) | Safe sex info | News info | Trustworthy | Easy to understand | Easy to find |
| Panel A. Overall effects | | | | | | |
| Treatment | .877*** | .185*** | .155*** | .262*** | .333*** | .247*** |
| | (.074) | (.043) | (.043) | (.039) | (.038) | (.038) |
| | p = .000 | p = .000 | p = .000 | p = .000 | p = .000 | p = .000 |
| Panel B. Heterogeneous treatment effects by internet experience | | | | | | |
| Treatment x no past internet use | .831*** | .213*** | .242*** | .309*** | .391*** | .380*** |
| | (.102) | (.059) | (.059) | (.057) | (.055) | (.054) |
| | p = .000 | p = .000 | p = .000 | p = .000 | p = .000 | p = .000 |
| Treatment x past internet use | .920*** | .160*** | .071 | .218*** | .277*** | .118** |
| | (.102) | (.060) | (.059) | (.054) | (.050) | (.051) |
| | p = .000 | p = .008 | p = .230 | p = .000 | p = .000 | p = .030 |
| Panel C. Heterogeneous treatment effects by achievement | | | | | | |
| Treatment x low achiever | .867*** | .183*** | .207*** | .266*** | .334*** | .261*** |
| | (.100) | (.059) | (.059) | (.054) | (.052) | (.053) |
| | p = .000 | p = .003 | p = .000 | p = .000 | p = .000 | p = .000 |
| Treatment x high achiever | .887*** | .188*** | .098 | .259*** | .332*** | .231*** |
| | (.110) | (.062) | (.061) | (.058) | (.054) | (.055) |
| | p = .000 | p = .003 | p = .133 | p = .000 | p = .000 | p = .000 |
| Mean of dependent variable in control | .000 | .457 | .377 | .436 | .495 | .542 |
| Strata FE | yes | yes | yes | yes | yes | yes |
| Number of students | 549 | 536 | 548 | 549 | 549 | 549 |

*Notes:* (1) refers to the index calculated over correct answers to the following questions: "Can you find information about world news events on Wikipedia?", "Can you find the MSCE results for students from your school on Wikipedia?", "Can you watch movies on Wikipedia?", "Can you communicate with friends on Wikipedia?", and if the Wikipedia app was recognized among seven other apps (not prompted). (2) refers to the question "What is the best place to find information about safe sex?" Students were asked to rank the following six options: a teacher, books in the school, Wikipedia, internet (other sites), another student, a family member. Coded as one if Wikipedia was ranked higher than internet (other sites). (3) refers to the question "What is the best place to find information about news events?" where, again, students ranked options. (4) to (6) are indicators calculated based on answers to the question"How is Wikipedia better than other sites on the internet?" (4) is equal to one if option "Information on Wikipedia is more trustworthy" was chosen. (5) if "It is easier to understand information on Wikipedia" was chosen. (6) if "It is easier to find information on Wikipedia" was chosen. Other alternatives were "There is more information on Wikipedia", "There are more things to do on Wikipedia", and "Don't know". "No past internet use" is equal to one if student reported never having used internet at the baseline. High (low) achievers defined as above (below) median exam scores at the baseline. The sample is students in the treatment group and in the subsample of the control group with supplementary surveys. All regressions include strata fixed effects. Randomization was stratified by school, form, above median achievement and past internet use. Robust standard errors in parentheses. * p<.10, ** p<.05, *** p<.01. Randomization inference p-values based on 10,000 replications denoted as "p =".

Appendix Table A5: Treatment Effects on Exam Scores, Primary Outcomes, No Baseline Scores

| | (1) English | (2) Biology |
|---|---|---|
| Panel A. Overall effects | | |
| Treatment | .097* | .084 |
| | (.056) | (.052) |
| | p = .092 | p = .112 |
| Panel B. Heterogeneous treatment effects | | |
| Treatment x low achiever | .180** | .179** |
| | (.085) | (.074) |
| | p = .051 | p = .018 |
| Treatment x high achiever | .007 | -.021 |
| | (.070) | (.070) |
| | p = .925 | p = .780 |
| Mean of dependent variable in control | .000 | .000 |
| Strata FE | yes | yes |
| Number of students | 1412 | 1406 |

*Notes:* Treatment effects on final exam scores. High (low) achievers defined as above (below) median exam scores at the baseline. All regressions include strata fixed effects. Randomization was stratified by school, form, above median achievement and past internet use. Robust standard errors in parentheses. * p<0.10, ** p<0.05, *** p<0.01. Randomization inference p-values based on 10,000 replications denoted as "p =".

Appendix Table A6: Treatment Effects on Exam Scores, Other School Subjects, No Baseline Scores

| | (1) Science | (2) Human. | (3) Math | (4) Chichewa | (5) Points | (6) Pass |
|---|---|---|---|---|---|---|
| Panel A. Overall effects | | | | | | |
| Treatment | .027 | .056 | .085 | -.061 | .591 | .023 |
| | (.057) | (.058) | (.058) | (.061) | (.476) | (.021) |
| | p = .614 | p = .316 | p = .131 | p = .315 | p = .222 | p = .260 |
| Panel B. Heterogeneous treatment effects | | | | | | |
| Treatment x low achiever | .085 | .191** | .200** | -.048 | 1.157 | .051 |
| | (.087) | (.085) | (.080) | (.086) | (.720) | (.034) |
| | p = .304 | p = .032 | p = .008 | p = .591 | p = .119 | p = .153 |
| Treatment x high achiever | -.033 | -.093 | -.034 | -.076 | -.021 | -.004 |
| | (.073) | (.079) | (.082) | (.087) | (.609) | (.023) |
| | p = .647 | p = .166 | p = .673 | p = .348 | p = .975 | p = .854 |
| Mean of dependent variable in control | .000 | .000 | .000 | .000 | -26.448 | .867 |
| Strata FE | yes | yes | yes | yes | yes | yes |
| Number of students | 1370 | 1396 | 1376 | 1398 | 1399 | 1381 |

*Notes:* Treatment effects on final exam scores. Science is a summary index of Chemistry and Physics. Humanities is a summary index of Agriculture, Geography, History, Life Skills and Social Science. Points is a measure of the students final overall grade. For each subject, the percentage scores is converted to a number of points between 1 and 9, where 1 is the best score, and 9 is the lowest score. The conversion is provided by the Malawi National Examinations Board (MANEB). The total number of points, also determined by MANEB, is the number of points obtained in English plus the number of points in the five other best subjects, where the best score is 6 points and the worst possible score is 54. We multiply the total number of points by -1 to ease interpretation of the coefficients in (5). Pass is an indicator equal to one if a student passes the school year. To pass the school year, students must pass their English course and five other courses and obtain a score of 6 points or less in at least one course. High (low) achievers defined as above (below) median exam scores at the baseline. All regressions include strata fixed effects. Randomization was stratified by school, form, above median achievement and past internet use. Robust standard errors in parentheses. * p<0.10, ** p<0.05, *** p<0.01. Randomization inference p-values based on 10,000 replications denoted as "p =".

Appendix Table A7: Treatment Effects on Exam Scores with Spillover Controls

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|---|
| | Biology | | | | English | | | |
| Treatment | .062 | .148 | | | .102** | .180 | | |
| | (.047) | (.091) | | | (.050) | (.098) | | |
| Treatment x low achiever | | | .149** | .214** | | | .196*** | .253** |
| | | | (.066) | (.100) | | | (.075) | (.108) |
| Treatment x high achiever | | | -.035 | -.040 | | | -.001 | .063 |
| | | | (.064) | (.104) | | | (.062) | (.110) |
| Treated study friends | -.010 | -.029 | -.010 | -.026 | -.004 | -.021 | -.004 | -.018 |
| | (.013) | (.021) | (.013) | (.021) | (.014) | (.023) | (.014) | (.023) |
| Study friends | .016*** | .016*** | .016*** | .016*** | .006 | .006 | .006 | .006 |
| | (.004) | (.004) | (.004) | (.004) | (.005) | (.005) | (.005) | (.005) |
| Control x treated study friends | | .023 | | .019 | | .021 | | .016 |
| | | (.021) | | (.021) | | (.023) | | (.023) |
| Mean of dependent variable in control | .000 | .000 | .000 | .000 | .000 | .000 | .000 | .000 |
| Strata FE | yes | yes | yes | yes | yes | yes | yes | yes |
| Number of students | 1,406 | 1,406 | 1,406 | 1,406 | 1,412 | 1,412 | 1,412 | 1,412 |

*Notes:* Treatment effects on final exam scores. (1), (3), (5) and (7): covariates include the treatment indicator, number of treated study friends and number of study friends. (2) , (4), (6) and (8) add controls for the number of treated study friends interacted with control student indicator. Study friend network collected at the baseline. A link is considered to be present if either student nominates the other during the three-day recall based on the question "With whom did you study with [yesterday]?". High (low) achievers defined as above (below) median exam scores at the baseline. In all regressions we include a control for the baseline measure of the outcome, an indicator for missing baseline measure, and strata fixed effects. Randomization was stratified by school, form, above median achievement and past internet use. Robust standard errors in parentheses. * p<0.10, ** p<0.05, *** p<0.01.

Appendix Table A8: Tercile Specification for Heterogeneous Treatment Effects

| | (1) English | (2) Biology |
|---|---|---|
| Treatment x bottom tercile | .239*** | .136* |
| | (.092) | (.080) |
| | p = .016 | p = .093 |
| Treatment x middle tercile | .058 | .119 |
| | (.081) | (.080) |
| | p = .523 | p = .173 |
| Treatment x top tercile | .001 | -.050 |
| | (.078) | (.079) |
| | p = .987 | p = .539 |
| Mean of dependent variable in control | .000 | .000 |
| Strata FE | yes | yes |
| Number of students | 1,412 | 1,406 |

*Notes:* Treatment effects on final exam scores. We include indicators for each tercile of baseline scores as controls. We include a control for baseline exam score with an indicator for missing baseline score. All regressions include strata fixed effects. Randomization was stratified by school, form, above median achievement and past internet use. Robust standard errors in parentheses. * p<0.10, ** p<0.05, *** p<0.01. Randomization inference p-values based on 10,000 replications denoted as "p =".

Appendix Table A9: Slope Specification for Heterogeneous Treatment Effects

| | (1) English | (2) Biology |
|---|---|---|
| Treatment | .082* | .075 |
| | (.048) | (.046) |
| | p = .104 | p = .113 |
| Treatment x baseline score | -0.091 | -.103** |
| | (.056) | (.044) |
| | p = .112 | p = .022 |
| Treatment x missing baseline score | .292 | -.094 |
| | (.424) | (.318) |
| | p = .473 | p = .761 |
| Mean of dependent variable in control | .000 | .000 |
| Strata FE | yes | yes |
| Number of students | 1,412 | 1,406 |

*Notes:* Treatment effects on final exam scores. Baseline score is the standardized average of English and Biology scores at baseline. We include controls for baseline exam scores with indicators for missing baseline scores, for both the Biology-English average and the outcome subject. All regressions include strata fixed effects. Randomization was stratified by school, form, above median achievement and past internet use. Robust standard errors in parentheses. * p<0.10, ** p<0.05, *** p<0.01. Randomization inference p-values based on 10,000 replications denoted as "p =".

Appendix Table A10: Heterogeneous Effects by Socioeconomic Status

| | (1) | (2) |
|---|---|---|
| | English | Biology |
| Treatment x low SES | .076 | .075 |
| | (.078) | (.070) |
| | p = .308 | p = .292 |
| Treatment x high SES | .124* | 0.052 |
| | (.065) | (.064) |
| | p = .086 | p = .437 |
| Mean of dependent variable in control | .000 | .000 |
| Strata FE | yes | yes |
| Number of students | 1,410 | 1,404 |

*Notes:* Treatment effects on final exam scores. High socioeconomic status (SES) is an indicator for having both running water and electricity at home (48 percent of students). We include a control for baseline socioeconomic status, and baseline exam score with an indicator for missing baseline score. All regressions include strata fixed effects. Randomization was stratified by school, form, above median achievement and past internet use. Robust standard errors in parentheses. * p<0.10, ** p<0.05, *** p<0.01. Randomization inference p-values based on 10,000 replications denoted as "p =".

# Restricted Access: How the Internet Can Be Used to Promote Reading and Learning

Laura Derksen, Catherine Michaud-Leclerc and Pedro CL Souza

## Supplementary Materials

## For Online Publication

## Classroom Introduction to the Project

- We are working for the University of Toronto in Canada for a research project
- The research project will take place in this school for the entire school year in which some students in Forms 2-4 will have access to a digital library with phones with access to an online encyclopedia.
- First, we would like to survey every student in Forms 2-4.
- The survey is not too long – about 10-20 minutes
- After the survey is finished, we are going to select some students for the mobile phone program
- The students are going to be selected RANDOMLY – it is not the best students. Every student in Forms 2-4 has the chance to be selected. [Make sure this is extremely clear]
- We cannot select every student, only a few students will be selected
- During the year, those selected students will be able to take part in a digital library program
- A digital library will be set up in [classroom]
- There will be a number of mobile phones with access to an online encyclopedia

- Students taking part in the program will be able to search online for information about their studies and other information [see examples below]
- If you are not selected for the program, you are free to ask selected students to search for something or to explain what they have learned
- If you are selected, you are free to take part or to refuse, you are not obligated to use the digital library
- We will continue to ask some students to answer short surveys throughout the year – these will include some selected students and other students
- Any questions?
- Looking forward to seeing you again when we will be conducting the survey

## About Wikipedia

A lot of information can be accessed on Wikipedia. This includes information about academics, health, politics, world news, sports and entertainment.

For example, suppose your Biology teacher says that next week you will start the topic of photosynthesis. If you search Wikipedia, you will find a detailed explanation of the process of photosynthesis, with equations and illustrations.

I will give you another example. Suppose you did not understand the different types of soil you discussed in agriculture class. You can use Wikipedia to find out more about the topic, including the definition of soil and the various types of soil. Wikipedia includes information about soil fertility, soil formation and the different functions of the soil.

In Wikipedia, you can find information about almost any topic from your studies. For example, you can find information about chemical reactions and the periodic table in chemistry, matter in physics and volcanos in geography. You can even review different rules you learn in M;athematics such as the rules for exponents. You can find information about local and international authors.

If you are thinking about what you want to do after secondary school, you can search Universities in Malawi and you will find a list of all colleges, public and private universities in Malawi. You can even look into the careers you may be interested in pursuing.

As we said, there is information just about everything on Wikipedia. If you want to know more about menstruation, birth control or pregnancy, you will find it in Wikipedia. Wikipedia talks also about different diseases such as malaria, Ebola and HIV. You can find information about the causes, symptoms and prevention.

You can find information about local politics and international news. You can find information about sports stars like Lionel Messi, and celebrities like Jay-Z or Nicki Minaj.

We think this project will help you a lot with your studies. Even if you are not selected for the program, you can ask your friends to search for information on a topic from class. If you are selected, you can share what you learn with your classmates.

# Digital Library Induction

## Instructions for Digital Librarians

- The induction should be done in small groups – enough so that each student can use one phone. Only for selected students
- Explain the digital library itself; Opening hours
- Explain Wikipedia. What it is, what kind of information you can find
- Explain privacy. Anonymous, you are free to search anything.
- You can only use Wikipedia. Everything else is blocked
- Practice together. Give several examples of things to search for (e.g. photosynthesis and Malawi).
- Show how to solve common problems. How to get back to search page (home three dots OR icon). Show what happens if they try to click on external links or restart the phone

## How to Use the Digital Library

- There are 12 phones in the digital library

- Sign in with the librarian
- If all phones are in use, join the waiting list or come back later
- If there is a waiting list, students are restricted to 30 minutes (35-40 minutes when the network is not good)
- Use the phone within the library
- Do no try to tamper with the phones
- There are no backup phones so if one breaks or goes missing there will be fewer phones to use
- Privacy. Your searches are anonymous – no one can see what you personally searched for (not the researchers, not the field team, not the teachers). This is a very important point – make sure they students can explain it back.

## Digital Library Rules

1. Only selected students can use the digital library
2. When you arrive, sign in with the digital librarian.
3. The phones should be used one by one (not in pairs)
4. Take care not to damage or tamper with the phone
5. Do not try to access other websites than Wikipedia
6. When you are done, return the phone to the digital librarian
7. Do not hand the phone to any other student

If you break the rules you will be suspended or removed from the program

Supplementary Table S1: Classification of News Events in 2017-18 (I/II)

| Date | Description | Africa |
|---|---|---|
| 11/2/17 | New species of Orangutan | no |
| 11/3/17 | ISIL defeated in Syria | no |
| 11/5/17 | Appleby scandal | no |
| 11/5/17 | Sutherland Springs shooting | no |
| 11/12/17 | Earthquake in Iran and Iraq | no |
| 11/15/17 | Robert Mugabe arrested | yes |
| 11/15/17 | da Vinci auction | no |
| 11/15/17 | ARA San Juan missing | no |
| 11/20/17 | Oumuamua asteroid detected | no |
| 11/22/17 | Mladic found guilty | no |
| 11/24/17 | Mosque attack in Egypt | yes |
| 12/5/17 | Russia banned from Winter Olympics | no |
| 12/6/17 | US recognizes Jerusalem as Israeli capital | no |
| 12/9/17 | Iraq liberated from ISIS | no |
| 12/14/17 | Disney acquires 21st Century Fox | no |
| 12/22/17 | UN imposes sanctions to North Korea | no |
| 12/24/17 | Guatemala recognizes Jerusalem as Israeli capital | no |
| 1/13/18 | Killing of Mehsud in Pakistan | no |
| 1/20/18 | Turkey invades northern Syria | no |
| 1/20/18 | US Federal government shutdown | no |
| 1/24/18 | China announces cloning of monkeys | no |
| 1/31/18 | Total lunar eclipse | no |
| 2/6/18 | Falcon Heavy launch | no |
| 2/9/18 | Winter Olympics starts | no |
| 2/10/18 | First female archbishop nominated | no |
| 2/11/18 | Saratov Airlines crash in Russia | no |
| 2/14/18 | Jacob Zuma resigns | yes |
| 2/14/18 | Majory school shooting | no |
| 2/18/18 | Iran Aseman Airlines crash | no |
| 3/4/18 | Skripal poisoning | no |
| 3/6/18 | Russian Air Force crash | no |
| 3/9/18 | Winter paralympics start | no |
| 3/9/18 | Trump accepts meeting with Kim Jong-un | no |
| 3/11/18 | Jinping named President for Life in China | no |
| 3/12/18 | US-Bangla Airlines crash in Nepal | no |
| 3/14/18 | School walkout in response to shootings in the US | no |
| 3/18/18 | Putin re-elected president | no |
| 3/19/18 | White rhino declared extinct | no |
| 3/23/18 | Carcassone terrorist attack | no |
| 3/24/18 | Demonstrations against gun violence | no |
| 3/25/18 | Quantas launches Perth-London flight | no |
| 3/25/18 | Kemerovo fire | no |
| 3/26/18 | Russian diplomats expelled in the wake of Skripal poisoning | no |
| 3/28/18 | Kim Jong-un meets Xi Jinping | no |
| 3/28/18 | Fire in Valencia, Venezuela | no |
| 4/4/18 | Commonwealth games start | no |
| 4/5/18 | Lula arrested | no |
| 4/6/18 | Humboldt Broncos crash | no |
| 4/8/18 | Sarin attack in Douma, Syria | no |
| 4/11/18 | Algerian Air Force crash | no |
| 4/14/18 | Syrian bases bombed by US | no |
| 4/18/18 | Nicaragua protests | no |
| 4/18/18 | Movie theathers open in Saudi Arabia | no |
| 4/18/18 | NASA TESS satellite launched | no |
| 4/19/18 | Diaz-Canel sworn President of Cuba | no |
| 4/19/18 | Swaziland changes name to Eswatini | yes |
| 4/23/18 | Toronto van attack | no |
| 4/27/18 | Kim Jong-un meets Moon Jae-in in the DMZ | no |
| 5/3/18 | ETA announces dissolution | no |
| 5/3/18 | Volcano Puna erupts | no |
| 5/5/18 | Insight probe launched | no |
| 5/8/18 | Trump withdrawals from Iranian nuclear agreement | no |
| 5/8/18 | Eurovision contest starts | no |
| 5/9/18 | Pakaran Harapan coallition wins majority in Malaysia | no |

*Notes*: All major newsworthy events as reported in `https://en.wikipedia.org/wiki/2017` and `https://en.wikipedia.org/wiki/2018` during the experiment. "Africa" refers to whether the events were considered to be physically occurring in Africa or relative to African states or politicians.

# Endline A survey

## Time Use and Resources Module

What time did you wake up yesterday?

Yesterday did you study alone? [Yes; No; Do not remember]

[If Yes] How much time did you study alone? [Hours, Minutes]

Yesterday did you study with others? [Yes; No; Do not remember]

[If Yes] How much time did you study with others? [Hours, Minutes]

[If Yes] With whom did you study?

Yesterday, did you eat breakfast, lunch, or dinner together with friends? [Yes; No; Do not remember]

[If Yes] With whom did you eat?

Yesterday, did you just hang out, had conversations or play with friends? [Yes; No; Do not remember]

[If Yes] How much time did you spend? [Hours, Minutes]

[If Yes] With whom?

Did you participate in a school club yesterday? [Yes; No; Do not remember]

[If Yes] Which school clubs did you participate in yesterday?

[If Yes] How much time did you spend participating in clubs yesterday? [Hours, Minutes]

Did you participate in a religious activity yesterday? [Yes; No; Do not remember]

[If Yes] Which religious activities did you participate in yesterday?

[If Yes] How much time did you spend participating in religious activities yesterday? [Hours, Minutes]

Did you participate in sports activities yesterday? [Yes; No; Do not remember]

[If Yes] Which sports activities did you participate in yesterday?

[If Yes] How much time did you spend participating in sports yesterday? [Hours, Minutes]

Are there any other activities you did yesterday? [Yes; No; Do not remember]

[If Yes] What are the other activities that you participated in yesterday?

[If Yes] How much time did you spend doing these other activities yesterday? [Hours, Minutes]

Think about each of the subjects you had yesterday. Did you raise your hand and speak in class? [Yes; No; Do not remember]

[If Yes] Which subject(s)?

What time did you go to sleep yesterday?

(Enumerator) Two/three/four/five/six/seven days ago it was ... [Sunday; Monday; Tuesday; Wednesday; Thursday; Friday; Saturday]

What time did you wake up on ... [day]?

On [day], did you study alone? [Yes; No; Do not remember]

[If Yes] How much time did you study alone? [Hours, Minutes]

On [day], did you study with others? [Yes; No; Do not remember]

[If Yes] How much time did you study with others? [Hours, Minutes]

[If Yes] With whom?

On [day], did you eat breakfast, lunch, or dinner together with friends? [Yes; No; Do not remember]

[If Yes] With whom did you eat?

On [day], did you just hang out, had conversations or play with friends? [Yes; No; Do not remember]

[If Yes] How much time did you spend? [Hours, Minutes]

[If Yes] With whom?

Did you participate in a school club on[day]? [Yes; No; Do not remember]

[If Yes] Which school clubs did you participate in on[day]?

[If Yes] How much time did you spend participating in clubs on [day]? [Hours, Minutes]

Did you participate in a religious activity on [day]? [Yes; No; Do not remember]

[If Yes] Which religious activities did you participate in on [day]?

[If Yes] How much time did you spend participating in religious activities on [day]? [Hours, Minutes]

Did you participate in sports activities on [day]? [Yes; No; Do not remember]

[If Yes] Which sports activities did you participate in on [day]?

[If Yes] How much time did you spend participating in sports on [day]? [Hours, Minutes]

Are there any other activities you did on [day]? [Yes; No; Do not remember]

[If Yes] What are the other activities that you participated in on [day]?

[If Yes] How much time did you spend doing these other activities on [day]? [Hours, Minutes]

Think about each of the subjects you had on [day]? Did you raise your hand and speak in class? [Yes; No; Do not remember]

[If Yes] Which subject(s)?

What time did you go to sleep on [day]?

## Social Networks Module

Think of students at this SCHOOL.

Who is your best friend?

If you could choose who to study with, who would you choose? Start with your first choice.

Have you borrowed money from a student at this school since the start of the school year? [Yes; No; Do not remember]

[If Yes] Who have you borrowed money from? Start with most recent.

Have you borrowed things from a student at this school since the start of the school year? [Yes; No; Do not remember]

[If Yes] Who have you borrowed things from? Start with most recent.

Have you given a gift to a student at this school since the start of the school year? [Yes; No; Do not remember]

[If Yes] Who have you given a gift to? Start with most recent.

Who do you talk to about personal topics or ask for advice? Start with first choice.

Who do you attend religious activities with? Start with most often.

Who do you talk to about movies, music, sports and entertainment? Start with first choice.

Who do you ask for information that might be useful when researching for a topic learned in class? Start with first choice.

Who do you ask for information about the news? Start with first choice.

Who do you ask for information about health? Start with first choice.

Who do you ask for information about school activities? Start with first choice.

Now think of students in your CLASS.

Who is the best academic student in your class?

Who is the most popular student in your class?

Who is the best at leading a group in your class?

If we want to spread information to everyone in your class about an event at the school, to whom should we speak?

We will hold a lottery for a prize at the end of this study. We will enter your name in the lottery and the name of three of your friends in this SCHOOL. Who would you like to nominate? This is private: no one will know if you nominated them.

## Information Module

We would like to ask you some questions about your beliefs. These questions are not a quiz – you should just answer what you believe is true. I will start with some questions about HIV and pregnancy.

Imagine a woman who has a menstrual cycle every month. She will be fertile on certain days every month. This is called the fertile window. That means if she has sex on those days, she might get pregnant. How many fertile days does an average woman have every cycle?

(a) 1-4 days

(b) 5-7 days

(c) 7-12 days

(d) more than 12 days

(e) Don't know

(f) Refuse to answer

On a scale of 1-5, where 1 is not certain at all, and 5 is very certain, how certain are you of your answer?

(a) 1 = Not certain at all

(b) 2 = Not very certain

(c) 3 = Neutral

(d) 4 = Certain

(e) 5 = Very Certain

Imagine an HIV-positive man who has sex with an HIV-negative woman one time. What is the approximate chance that she gets HIV? This is called the HIV transmission rate.

(a) 100% chance – she will definitely get HIV

(b) 50% chance – she has a 50/50 chance of getting HIV

(c) 10% chance – in a single time she will probably not get HIV

(d) Less than 1% chance – in a single time she will probably not get HIV

(e) Don't know

(f) Refuse to answer

On a scale of 1-5, where 1 is not certain at all, and 5 is very certain, how certain are you of your answer?

(a) 1 = Not certain at all

(b) 2 = Not very certain

(c) 3 = Neutral

(d) 4 = Certain

(e) 5 = Very Certain

ARVs stands for antiretrovirals – these are the drugs that are used to treat HIV. Some people think we should use ARVs to prevent transmission for example between a husband and wife – this is called "treatment as prevention". Do you think ARVs can stop a person living with HIV from spreading the virus?

(a) No

(b) Yes, ARVs can reduce the chance of spreading the virus but most of the time the virus will still spread

(c) Yes, as soon as a person starts taking ARVs they cannot spread the virus at all

(d) description Yes, a person who has been taking ARVs properly for a long time will almost never spread the virus

(e) Don't know

(f) Refuse to answer

On a scale of 1-5, where 1 is not certain at all, and 5 is very certain, how certain are you of your answer?

(a) 1 = Not certain at all

(b) 2 = Not very certain

(c) 3 = Neutral

(d) 4 = Certain

(e) 5 = Very Certain

Imagine a student who has a hard time to see the chalkboard and sometimes complains about a blurry vision. It is possible that this student has myopia. Myopia is a condition that affects about 5% - 10% of young teenagers who cannot see properly at far distances. What do you think is the best way to correct myopia for this student?

(a) The student should sit at the front of the class.

(b) Eye drops can correct myopia and help with the blurry vision.

(c) The student should take an eye test. Eye glasses will correct the myopia and improve their vision.

(d) The student does not need eye glasses. Eye glasses are mostly for older people.

(e) Don't know

(f) Refuse to answer

On a scale of 1-5, where 1 is not certain at all, and 5 is very certain, how certain are you of your answer?

(a) 1 = Not certain at all

(b) 2 = Not very certain

(c) 3 = Neutral

(d) 4 = Certain

(e) 5 = Very Certain

Now we are going to do a quiz. At the end of the study, there will be a lottery for some prizes. For each quiz question you get right you will get one lottery ticket. We won't tell you the answer now, but we will give you one more chance to get these questions right at the last survey. You can keep this piece of paper. We will ask the questions again in the next survey, and you will get one lottery ticket for each question you get right. This is different from the other paper we gave you – only this one counts for the quiz and the lottery tickets.

When is your last exam?

We would like to interview you one more time. As we mentioned, at that point there will be a lottery for some prizes.

Thank you, that is the end of the survey. Please go and find [next student] and send them here.

# Endline B survey

## Background Module

Have you ever used internet before? [Yes; No; Do not remember]

How often did you use the internet when you were at home over the break between terms 2 and 3? [Almost every day; At least once per week; Less than once per week; Not at all]

What do you usually use the internet for?

Have you ever used Wikipedia? [Yes; No; Do not remember]

## Ability to Use IT Module

Can you find information about world news events on the internet? [Yes; No; Do not know]

Can you find information about world news events on Wikipedia? [Yes; No; Do not know]

Can you find the MSCE results for students from your school on the internet? [Yes; No; Do not know]

Can you find the MSCE results for students from your school on Wikipedia? [Yes; No; Do not know]

Can you watch movies on the internet? [Yes; No; Do not know]

Can you watch movies on Wikipedia? [Yes; No; Do not know]

Can you communicate with friends on the internet? [Yes; No; Do not know]

Can you communicate with friends on Wikipedia? [Yes; No; Do not know]

How is Wikipedia better than other sites on the internet?

How are other sites on the internet better than Wikipedia?

What is the best place to find information for *English class*? Rank these options from 1 = best to 6 = worst. [A teacher; Books in the school; Wikipedia; Internet (other sites); Another student; A family member]

What is the best place to find information for *Chichewa class*? Rank these options from 1 = best to 6 = worst. [A teacher; Books in the school; Wikipedia; Internet (other sites); Another student; A family member]

What is the best place to find information for *Biology class*? Rank these options from 1 = best to 6 = worst. [A teacher; Books in the school; Wikipedia; Internet (other sites); Another student; A family member]

What is the best place to find information for *Physics class*? Rank these options from 1 = best to 6 = worst. [A teacher; Books in the school; Wikipedia; Internet (other sites); Another student; A family member]

What is the best place to find information for *Math class*? Rank these options from 1 = best to 6 = worst. [A teacher; Books in the school; Wikipedia; Internet (other sites); Another student; A family member]

What is the best place to find information about *safe sex*? Rank these options from 1 = best to 6 = worst. [A teacher; Books in the school; Wikipedia; Internet (other sites); Another student; A family member]

What is the best place to find information about *news events*? Rank these options from 1 = best to 6 = worst. [A teacher; Books in the school; Wikipedia; Internet (other sites); Another student; A family member]

## Aspirations, Career and Life Expectations Module

I am a person who is outgoing and sociable.

(a) 1 = Strongly Disagree

(b) 2 = Disagree

(c) 3 = Neither Agree or Disagree

(d) 4 = Agree

(e) 5 = Strongly Agree

I am a person who is original and comes up with new ideas.

(a) 1 = Strongly Disagree

(b) 2 = Disagree

(c) 3 = Neither Agree or Disagree

(d) 4 = Agree

(e) 5 = Strongly Agree

I am a person who is helpful and unselfish with others.

(a) 1 = Strongly Disagree

(b) 2 = Disagree

(c) 3 = Neither Agree or Disagree

(d) 4 = Agree

(e) 5 = Strongly Agree

I am a person who is sometimes shy and inhibited.

(a) 1 = Strongly Disagree

(b) 2 = Disagree

(c) 3 = Neither Agree or Disagree

(d) 4 = Agree

(e) 5 = Strongly Agree

I am a person who is curious about many different things.

(a) 1 = Strongly Disagree

(b) 2 = Disagree

(c) 3 = Neither Agree or Disagree

(d) 4 = Agree

(e) 5 = Strongly Agree

I am more ambitious than most people.

(a) 1 = Strongly Disagree

(b) 2 = Disagree

(c) 3 = Neither Agree or Disagree

(d) 4 = Agree

(e) 5 = Strongly Agree

I think that the world is a good place.

(a) 1 = Strongly Disagree

(b) 2 = Disagree

(c) 3 = Neither Agree or Disagree

(d) 4 = Agree

(e) 5 = Strongly Agree

I feel that life is very rewarding.

(a) 1 = Strongly Disagree

(b) 2 = Disagree

(c) 3 = Neither Agree or Disagree

(d) 4 = Agree

(e) 5 = Strongly Agree

I feel able to take anything on.

(a) 1 = Strongly Disagree

(b) 2 = Disagree

(c) 3 = Neither Agree or Disagree

(d) 4 = Agree

(e) 5 = Strongly Agree

I often experience joy and elation.

(a) 1 = Strongly Disagree

(b) 2 = Disagree

(c) 3 = Neither Agree or Disagree

(d) 4 = Agree

(e) 5 = Strongly Agree

What is the likelihood that you will get married before you turn 20 years old?

(a) 0 = Already 20+ and did not marry before 20

(b) 1 = Very unlikely

(c) 2 = Unlikely

(d) 3 = Neutral

(e) 4 = Likely

(f) 5 = Very likely

(g) 6 = Already married before age 20

What is the likelihood that you will have a baby before you turn 20 years old?

(a) 0 = Already 20+ and did not have baby before 20

(b) 1 = Very unlikely

(c) 2 = Unlikely

(d) 3 = Neutral

(e) 4 = Likely

(f) 5 = Very likely

(g) 6 = Already had baby before age 20

How many children would you like to have in the future?

Would you prefer to have more sons or daughters?

(a) More daughters

(b) Equal number of daughters and sons.

(c) More sons

(d) I am indifferent

What career do you hope to have in the future?

Can you think of someone who is a role model for you? [Yes; No]

[If Yes] What is the name of one of your role models?

[If Yes] Have you met or talked to this person?

[If Yes] What is this person's profession?

[If Yes] Is this person male or female?

Which college or university do you think you will most likely attend?

Which program do you think you will most likely attend?

Which college or university would be your dream school?

Which program would you choose to attend at your dream school?

Do you have an idea to start a business? [Yes; No]

What is the likelihood that you will be successful in starting this business?

(a) 1 = Very unlikely

(b) 2 = Unlikely

(c) 3 = Neutral

(d) 4 = Likely

(e) 5 = Very likely

I am going to ask you some questions about health behaviour. I want to remind you that you can skip any question. For the next few questions, I want you to imagine a student who is similar to you.

In the next year, what is the likelihood that this student will have sex?

(a) 1 = Very unlikely

(b) 2 = Unlikely

(c) 3 = Neutral

(d) 4 = Likely

(e) 5 = Very likely

In the next year, what is the likelihood that this person will have sex without a condom?

(a) 1 = Very unlikely

(b) 2 = Unlikely

(c) 3 = Neutral

(d) 4 = Likely

(e) 5 = Very likely

## Gender and Empowerment Module

How much do you agree with the following statements?

... it may sometimes be fair for a husband to beat his wife

(a) 1 = Strongly Disagree

(b) 2 = Disagree

(c) 3 = Neither Agree or Disagree

(d) 4 = Agree

(e) 5 = Strongly Agree

... a woman's priority should be her children, husband and family

(a) 1 = Strongly Disagree

(b) 2 = Disagree

(c) 3 = Neither Agree or Disagree

(d) 4 = Agree

(e) 5 = Strongly Agree

... a woman is just as able as a man to lead a country

(a) 1 = Strongly Disagree

(b) 2 = Disagree

(c) 3 = Neither Agree or Disagree

(d) 4 = Agree

(e) 5 = Strongly Agree

## Interests and Abilities Module

What is your favourite school subject?

What are your interests?

## Time Use Module

Did you participate in a school club in the last term? [Yes; No; Do not remember]

[If Yes] Which school clubs did you participate in in the last term?

Did you participate in a religious activity in the last term? [Yes; No; Do not remember]

[If Yes] Which religious activities did you participate in last term?

Did you participate in sports activities last term? [Yes; No; Do not remember]

[If Yes] Which sports activities did you participate in last term?

Are there any other activities you did last term? [Yes; No; Do not remember]

[If Yes] What are the other activities that you participated in last term?

## Social Ties Module

Have you asked another student to search for information using the mobile library? [Yes; No; Do not remember]

[If Yes] Which student?

[If Yes] What type of information?

[If Yes] Was it related to any of the school subjects?

[If Yes] Did he or she give you the information you wanted?

Did any other student ask you to search for information using the mobile library? [Yes; No; Do not remember]

[If Yes] Which student?

[If Yes] What type of information?

[If Yes] Was it related to any of the school subjects?

[If Yes] Did he or she give you the information you wanted?

Did any teachers ask you to search for school-related information using the mobile library? [Yes; No; Do not remember]

[If Yes] For which subjects?

Did the mobile library program affect your friendships this year? [Yes; No; Do not know]

[If Yes] How? Please explain. You do not need to name specific friends.

## Information Module

We would like to ask you some questions about your beliefs. These questions are not a quiz – you should just answer what you believe is true. I will start with some questions about HIV and pregnancy.

Who is the most likely to be HIV-positive?

(a) A teenage boy aged 15-19

(b) A man aged 20-24

(c) A man aged 25-29

(d) They all have the same likelihood

(e) Don't know

(f) Refuse to answer

On a scale of 1-5, where 1 is not certain at all, and 5 is very certain, how certain are you of your answer?

(a) 1 = Not certain at all

(b) 2 = Not very certain

(c) 3 = Neutral

(d) 4 = Certain

(e) 5 = Very Certain

Imagine a woman who has a menstrual cycle every month. She will be fertile on certain days every month.This is called the fertile window. That means if she has sex on those days, she might get pregnant. How many fertile days does an average woman have every cycle?

(a) 1-4 days

(b) 5-7 days

(c) 7-12 days

(d) more than 12 days

(e) Don't know

(f) Refuse to answer

On a scale of 1-5, where 1 is not certain at all, and 5 is very certain, how certain are you of your answer?

(a) 1 = Not certain at all

(b) 2 = Not very certain

(c) 3 = Neutral

(d) 4 = Certain

(e) 5 = Very Certain

Where did you learn this information?

(a) Another student. [If selected] Which other student?

(b) Books in the school

(c) Family member

(d) Internet (other sites)

(e) Teacher

(f) Wikipedia

(g) Student guessed

Imagine an HIV-positive man who has sex with an HIV-negative woman one time. What is the approximate chance that she gets HIV? This is called the HIV transmission rate.

(a) 100% chance – she will definitely get HIV

(b) 50% chance – she has a 50/50 chance of getting HIV

(c) 10% chance – in a single time she will probably not get HIV

(d) Less than 1% chance – in a single time she will probably not get HIV

(e) Don't know

(f) Refuse to answer

On a scale of 1-5, where 1 is not certain at all, and 5 is very certain, how certain are you of your answer?

(a) 1 = Not certain at all

(b) 2 = Not very certain

(c) 3 = Neutral

(d) 4 = Certain

(e) 5 = Very Certain

Where did you learn this information?

(a) Another student. [If selected] Which other student?

(b) Books in the school

(c) Family member

(d) Internet (other sites)

(e) Teacher

(f) Wikipedia

(g) Student guessed

ARVs stands for antiretrovirals – these are the drugs that are used to treat HIV. Some people think we should use ARVs to prevent transmission for example between a husband and wife – this is called "treatment as prevention". Do you think ARVs can stop a person living with HIV from spreading the virus?

(a) No

(b) Yes, ARVs can reduce the chance of spreading the virus but most of the time the virus will still spread

(c) Yes, as soon as a person starts taking ARVs they cannot spread the virus at all

(d) Yes, a person who has been taking ARVs properly for a long time will almost never spread the virus

(e) Don't know

(f) Refuse to answer

On a scale of 1-5, where 1 is not certain at all, and 5 is very certain, how certain are you of your answer?

(a) 1 = Not certain at all

(b) 2 = Not very certain

(c) 3 = Neutral

(d) 4 = Certain

(e) 5 = Very Certain

Where did you learn this information?

(a) Another student. [If selected] Which other student?

(b) Books in the school

(c) Family member

(d) Internet (other sites)

(e) Teacher

(f) Wikipedia

(g) Student guessed

## Phone Test Module

Please look at this paper. How many of these apps do you recognize?

(a) Facebook

(b) Google

(c) Instagram

(d) Opera

(e) Reddit

(f) Snapchat

(g) Whatsapp

(h) Wikipedia

We would like to ask you a question. You can use this phone to help you find the answer.

How many stars are there in the Milky Way?
How long did the student take to find the answer? [Minutes, Seconds]
How well was the network working?

I will ask you to write your MOBILE LIBRARY USERNAME here. Do you remember it? Fill out the survey. Then we will fold this paper and put it in an envelope with all the other students. I will not be able to find your username and link it to you.

## Unfairness Module

Think of the students that had access to the mobile library. Do you think teachers treated those students differently? [Yes; No; Do not know]

[If Yes] How?

How fair was the mobile library program?

(a) 1 = Fair

(b) 2 = Somewhat fair

(c) 3 = Neutral

(d) 4 = Somewhat unfair

(e) 5 = Unfair

Why?
How upset were you that you were not selected for the program? (Control students)

(a) 1 = Very upset

(b) 2 = Upset

(c) 3 = Neutral

(d) 4 = A bit upset

(e) 5 = Not upset at all

Why?

On a scale from 1 to 5, are you glad that the mobile library came to your school? [1 = Not glad at all; 5 = Glad]

On a scale from 1 to 5, was the mobile library a good thing for your school? [1 = Bad thing; 5 Good thing]

Do you have some feedback you would like to share about the mobile library program?

## Knowledge Quiz Module

There are some extra tokens for the lottery. Here are two extra green tokens. If you want, you can have one of these extra tokens, but if you take it, we will also give an extra token to another student. This student will be chosen from those who DID NOT have access to the mobile library. What should we do? Will you take the extra token?

Here are two more extra green tokens. If you want, you can have one of these extra tokens, but if you take it, we will also give an extra token to another student. This student will be chosen from those who DID have access to the mobile library. Will you take the extra token?

Now we are going to do a quiz. There will be a lottery for some prizes. For each quiz question you get right you will get one lottery ticket.

What is the answer to ... [Question 1]?

Where did you learn this information?

(a) Another student. [If selected] Which other student?

(b) Books in the school

(c) Family member

(d) Internet (other sites)

(e) Teacher

(f) Wikipedia

(g) Student guessed

What is the answer to ... [Question 2]?

Where did you learn this information?

(a) Another student. [If selected] Which other student?

(b) Books in the school

(c) Family member

(d) Internet (other sites)

(e) Teacher

(f) Wikipedia

(g) Student guessed

Thank you, that is the end of the survey. Please go and find [next student] and send them here.

# Academic Questions – Sample

| **Biology Questions** |
|---|
| A spirochaete is a type of... |
| Which of the following bacteria is gram-negative? |
| Which of the following bacteria is gram-positive? |
| How do fungi acquire their food? |
| Penicillin is derived from penicillum, a type of |
| Cholera is a |
| Which of the following is an example of an endocrine gland? |
| Which of the following is both an endocrine and an exocrine gland? |
| Where is insulin produced? |
| **History Questions** |
| World War I began in which year? |
| Adolf Hitler was born in which country? |
| John F. Kennedy was assassinated in |
| Who fought in the war of 1812? |
| Which general famously stated "I shall return"? |
| American involvement in the Korean War took place in which decade? |
| The Battle of Hastings in 1066 was fought in which country? |
| The Magna Carta was published by the King of which country? |
| Who first successfully developed the printing press? |
| **Geography Questions** |
| Which of the following cities is the capital of Argentina? |
| Which ocean lies on the east coast of the United States? |
| How many Great Lakes are there in the United States/Canada? |
| Which is the world's highest mountain? |
| Which is the longest river in the World? |
| Which is the biggest desert in the World? |
| Which of this cities is not in Europe? |
| Which of the following cities is the capital of Netherlands? |
| Which of this is the largest city in Africa? |
| What is the capital of Turkey? |

# Examples from English Examinations

In this section, we provide examples of the multiple choice questions and composition questions that students have to take for their English classes. The questions were provided by the school administration.

Supplementary Figure S1: Sample of Multiple Choice Questions: English Examinations

4. We travelled_____train from Salima to Lilongwe
   A. on
   B. in
   C. through
   D. by
5. Everyone was surprised_____the bad weather.
   A. with
   B. by
   C. at
   D. for
6. The storm had_____when we started our journey.
   A. died away
   B. died out
   C. died off
   D. died down

## Sample of Composition Question: English Examinations

" – Answer one question only

– Spend the first 10 minutes reading the questions and planning your answers to the question chosen. Planning may include writing rough notes. Cross out your rough notes before you hand in your Answer Book.

– Marks will be awarded for layout, language, content and creativity. Candidates will be penalized for committing mechanical errors and writing answers that are short and /or off-point.

– You are expected to write between 350 and 500 words for the question you have chosen.

EITHER

1. Write an original short story entitled 'The Imposter' (40 marks)

2. Imagine that the area where you live was flooded. The floods destroyed homes and property. Write a report to the District Commissioner informing him or her of the disaster. (40 marks)"

# Topic Classifications and Browsing Tables

Supplementary Table S2: Random Sample of Pages and Topics Classifications

| **Wikipedia Page** | **Top Level Category** |
|---|---|
| The Showgrounds (Coleraine) | Category:Sports |
| King and Queen (sculpture) | Category:Arts |
| The Elder Scrolls V: Skyrim | Category:Entertainment |
| Nicolas-Claude Fabri de Peiresc | Category:People |
| Main Krishna Hoon | Category:Entertainment |
| T-tubule | Category:Life |
| Olympus Mons | Category:Geography |
| Christian Bale | Category:People |
| Macroshock | Category:Life |
| Premier Soccer League | Category:Events |
| Blood product | Category:Health |
| Postal stationery | Category:Economy |
| Room in Rome | Category:Arts |
| Juan Antonio Ramos | Category:Sports |
| List of Sofia the First characters | Category:Entertainment |
| Jamaica Defence Force | Category:World |
| Dannii Minogue discography | Category:Entertainment |
| Rosh Hashanah | Category:Religion |
| Glob Herman | Category:Entertainment |
| Isometry | Category:Mathematics |
| Crush (singer) | Category:Music |
| El Regreso del Sobreviviente | Category:Music |
| Warpath: Jurassic Park | Category:Entertainment |
| Hunter-gatherer | Category:Academic disciplines |
| Senegal national football team | Category:Sports |
| Steven St. Croix | Category:Entertainment |
| Emanuela Casti | Category:People |
| Sonam (actress) | Category:People |
| Don Prudhomme | Category:Sports |
| Primitive reflexes | Category:Academic disciplines |

*Notes:* A random sample of Wikipedia pages browsed by students and their associated topic classifications. See Section 3.2 and Appendix A for additional details.

Supplementary Table S3: Random Sample of Sex-Related Pages for Different Thresholds

| **Wikipedia Page** | **Fraction of Paths with Sex-Related Subcategory** |
|---|---|
| | **Preferred Threshold: $>$ 0.1** |
| Pornographic film actor | 0.1566 |
| Abortifacient | 0.1508 |
| ILGA-Europe | 0.1364 |
| PorYes | 0.1862 |
| Nikki Thomas (activist) | 0.1115 |
| History of erotic depictions | 0.1956 |
| Sex Worker Open University | 0.1111 |
| Another Lady Innocent | 0.1739 |
| Kegel exercise | 0.3158 |
| Ectopic pregnancy | 0.1692 |
| | **Less Conservative Threshold: $>$0.05,$<$0.1** |
| Shane (actress) | 0.0984 |
| Moan (film) | 0.0791 |
| Mary-Anne Kenworthy | 0.0750 |
| Evil Angel (studio) | 0.0594 |
| List of Playboy Playmates of 1992 | 0.0833 |
| The Opening of Misty Beethoven | 0.0635 |
| Futanari | 0.0851 |
| Hatsuinu | 0.0636 |
| Dogville | 0.0557 |
| Aitraaz | 0.0942 |
| | **No Threshold: $<$0.05** |
| Polygamy in Kenya | 0.0250 |
| List of Grand Theft Auto: Vice City characters | 0.0101 |
| Aquaman | 0.0028 |
| Patrick (given name) | 0.0248 |
| Grant Mitchell (EastEnders) | 0.0113 |
| Sex and Shopping | 0.0368 |
| Kyaa Kool Hain Hum 3 | 0.0051 |
| Les Paul and Mary Ford | 0.0060 |
| Amun | 0.0270 |
| Hotel King | 0.0150 |

*Notes:* A random sample of potentially sex-related Wikipedia pages, with three different definitions of "sex-related". The threshold represents the minimum fraction of paths through the Wikipedia category tree that must pass through a sex-related subcategory. See Section 3 and Appendix A for additional details.

# Supplementary Table S4: Mapping of Biology Syllabus to Wikipedia Pages or Categories (A to F)

| Biology Syllabus Topic | Wikipedia Page or Category | Biology Syllabus Topic | Wikipedia Page or Category |
|---|---|---|---|
| Abnormal conditions associated with reproduction | Category:Endocrine diseases | Contraception | Non-penetrative sex |
| Abnormal conditions associated with reproduction | Category:Endocrine disruptors | Contraception | Pearl Index |
| Abnormal conditions associated with reproduction | Category:Gynaecologic disorders | Contraception | Sexual abstinence |
| Abnormal conditions associated with reproduction | Category:Male genital disorders | Contraception | Sterilization (medicine) |
| Abnormal conditions associated with reproduction | Reproductive system disease | Defects of the eye and ear | Category:Ear |
| Abnormal conditions associated with the circulatory system | Category:Cardiovascular diseases | Defects of the eye and ear | Category:Eye |
| Abnormal conditions associated with the circulatory system | Category:Heart diseases | Defects of the eye and ear | Ear |
| Abnormal conditions associated with the circulatory system | Category:Lymphatic pathology | Defects of the eye and ear | Eye |
| Abnormal conditions associated with the circulatory system | Lymphatic disease | Defects of the eye and ear | Human eye |
| Abnormal conditions associated with the respiratory system | Category:Respiratory diseases | Deficiency diseases | Category:Protein-energy malnutrition |
| Abnormal conditions associated with the respiratory system | Respiratory failure | Deficiency diseases | Epidemiology of malnutrition |
| Abnormal conditions of the digestive system | Category:Digestive diseases | Deficiency diseases | Malnutrition |
| Abnormal conditions of the digestive system | Gastrointestinal disease | Deficiency diseases | Malnutrition in children |
| ADH and osmoregulation | Adipic acid dihydrazide | Deficiency diseases | Starvation |
| ADH and osmoregulation | Category:Cell biology | Deficiency diseases | Stunted growth |
| ADH and osmoregulation | Category:Membrane biology | Diarrhoeal diseases | Category:Diarrhea |
| ADH and osmoregulation | Osmoregulation | Diarrhoeal diseases | Diarrhea |
| Anaemia | Anaemia | Digestion | Category:Digestive system |
| Anaemia | Category:Anemias | Digestion | Digestion |
| Animal biology | Anatomy | Digestive enzymes | Category:Enzymes |
| Animal biology | Animal anatomy | Digestive enzymes | Digestive enzyme |
| Animal biology | Zoology | Digestive system | Human digestive system |
| Applications of biotechnology | Biotechnology | Diseases of the nervous system | Category:Central nervous system disorders |
| Artificial ventilation (resuscitation) | Artificial ventilation | Diseases of the nervous system | Neurological disorder |
| Artificial ventilation (resuscitation) | Category:Mechanical ventilation | Effects of alcohol and drug abuse on the nervous system | Category:Drugs acting on the nervous system |
| Balanced diet | Category:Dietetics | Effects of alcohol and drug abuse on the nervous system | Drug |
| Balanced diet | Nutrition | Effects of alcohol and drug abuse on the nervous system | Psychoactive drug |
| Biology | Biology | effects of human interaction on the environment | Category:Effects of global warming |
| Blood transfusion | Blood transfusion | Effects of physical factors on organisms | Environmental factor |
| Blood transfusion | Category:Transfusion medicine | Effects of salts and water intake on urine production | Fluid balance |
| Breathing mechanism | Breathing | Endocrine system | Category:Endocrine system |
| Breathing mechanism | Category:Respiration | Endocrine system | Endocrine system |
| Cancer | Cancer | Energy flow in a food chain | Energy flow (ecology) |
| Cancer | Category:Oncology | Estimating plant and animal populations | Category:Population ecology |
| Cell division | Category:Cellular processes | Ethical implications of the use of biotechnology | Bioethics |
| Cell division | Cell division | Excretory system | Category:Hepatology |
| Circulatory system | Category:Circulatory system | Excretory system | Category:Integumentary system |
| Circulatory system | Circulatory system | Excretory system | Category:Respiratory system |
| Classification of living things | Category:Taxonomy (biology) | Excretory system | Category:Urinary system |
| Classification of living things | Taxonomy (biology) | Excretory system | Excretory system |
| Common infectious diseases | Category:Bacterial diseases | External features of flowering and non-flowering plants | Category:Plants |
| Common infectious diseases | Category:Fungal diseases | External features of flowering and non-flowering plants | Flowering plant |
| Common infectious diseases | Category:Prions | External features of flowering and non-flowering plants | Plant |
| Common infectious diseases | Category:Protozoal diseases | Feeding structures in animals | Carnivore |
| Common infectious diseases | Category:Viral diseases | Feeding structures in animals | Herbivore |
| Common infectious diseases | Infection | Feeding structures in animals | List of feeding behaviours |
| Common sources of food nutrients | Category:Nutrients | Feeding structures in animals | Omnivore |
| Common sources of food nutrients | Nutrients | Fertilization and conception | Human fertilization |
| Conditioned reflexes | Classical conditioning | Fertilization and conception | Twin |
| Conditions for the growth of micro-organisms | Category:Microorganisms | First line defence | Category:Immune system |
| Conditions for the growth of micro-organisms | Micro-organisms | First line defence | Immune system |
| Contraception | Birth control | Food chains and food webs | Category:Ecological connectivity |
| Contraception | Category:Barrier contraception | Food chains and food webs | Food chain |
| Contraception | Category:Contraception for males | Food chains and food webs | Food web |
| Contraception | Category:Fertility awareness | Food nutrients | Nutrient |
| Contraception | Category:Hormonal contraception | Food tests | Category:Foodborne illnesses |
| Contraception | Category:Intrauterine contraception | Food tests | Food microbiology |
| Contraception | Category:Spermicide | Food tests | Food safety |
| Contraception | Coitus interruptus | Food tests | Foodborne illness |
| Contraception | Comparison of birth control methods | Functions of the liver in relation to digestion | Category:Liver |
| Contraception | Lactational amenorrhea | Functions of the liver in relation to digestion | Liver |
| Contraception | Long-acting reversible contraception | | |

*Notes:* See Section 3 and Appendix A for additional details.

# Supplementary Table S5: Mapping of Biology Syllabus to Wikipedia Pages or Categories (G to Z)

| Biology Syllabus Topic | Wikipedia Page or Category | Biology Syllabus Topic | Wikipedia Page or Category |
|---|---|---|---|
| Gaseous exchange in humans | Gas exchange | Plant structure and functions | Category:Plant physiology |
| Genes, GNA and chromosomes | Category:Chromosomes | Plant structure and functions | Plant anatomy |
| Genes, GNA and chromosomes | Chromosome | Plant structure and functions | Plant physiology |
| Genetics and evolution | Category:Evolutionary biology | Principles of Mendelian genetics | Category:Classical genetics |
| Genetics and evolution | Category:Genetics | Principles of Mendelian genetics | Mendelian inheritance |
| Genetics and evolution | Category:Population genetics | Process of birth | Birth |
| Genetics and evolution | Evolution | Process of birth | Category:Childbirth |
| Genetics and evolution | Evolutionary biology | Process of birth | Category:Maternal health |
| Genetics and evolution | Genetics | Process of birth | Childbirth |
| Genetics and evolution | Natural selection | Process of birth | Pregnancy |
| Genetics and evolution | Population genetics | Ratios of genotypes and phenotypes of offspring monohybrid crosses | Genotype |
| Genetics and evolution | Sexual selection | Ratios of genotypes and phenotypes of offspring monohybrid crosses | Monohybrid cross |
| How insulin is produced | Category:Human hormones | Ratios of genotypes and phenotypes of offspring monohybrid crosses | Phenotype |
| How insulin is produced | Insulin | Reflex actions | Category:Reflexes |
| How the dialysis machine works | Category:Renal dialysis | Reflex actions | Reflex |
| How the dialysis machine works | Dialysis | Respiratory system | Respiratory system |
| Human biology | Human anatomy | Role of blood cells | Blood cell |
| Human biology | Human biology | Role of blood cells | Category:Blood cells |
| Impulse transmission | Category:Neurophysiology | Role of blood cells | Category:Serology |
| Impulse transmission | Neurotransmission | Role of blood cells | Serology |
| Injuries to bones and joints | Bone fracture | Role of the heart in blood circulation | Blood |
| Injuries to bones and joints | Category:Bone fractures | Role of the heart in blood circulation | Category:Hematology |
| Injuries to bones and joints | Category:Dislocations, sprains and strains | Role of the heart in blood circulation | Heart |
| Injuries to bones and joints | Joint dislocation | Role of the heart in blood circulation | Hematology |
| Internal structure of vertebrates | Category:Skeletal system | Sense organs | Category:Sensory organs |
| Internal structure of vertebrates | Category:Vertebrates | Sense organs | Sense |
| Internal structure of vertebrates | Vertebrate | Sex determination and linkage | Sex linkage |
| invertebrates | Category:Invertebrates | Speciation | Category:Speciation |
| invertebrates | Invertebrate | Speciation | Speciation |
| Locomotion in human beings bones muscles | Bipedalism | STIs, HIV and AIDS | Bacterial vaginosis |
| Locomotion in human beings bones muscles | Bone | STIs, HIV and AIDS | Category:Chlamydia infections |
| Locomotion in human beings bones muscles | Category:Animal locomotion | STIs, HIV and AIDS | Category:Herpes |
| Locomotion in human beings bones muscles | Category:Bones | STIs, HIV and AIDS | Category:Infections with a predominantly sexual mode of transmission |
| Locomotion in human beings bones muscles | Category:Human physiology | | |
| Locomotion in human beings bones muscles | Category:Muscular system | STIs, HIV and AIDS | Gonorrhea |
| Locomotion in human beings bones muscles | Human leg | STIs, HIV and AIDS | Human papillomavirus infection |
| Locomotion in human beings bones muscles | Kinesiology | STIs, HIV and AIDS | Syphilis |
| Locomotion in human beings bones muscles | Muscle | STIs, HIV and AIDS | Zika virus |
| Locomotion in vertebrates | Category:Terrestrial locomotion | Structure of neurones | Category:Neurons |
| Locomotion in vertebrates | Terrestrial locomotion | Structure of neurones | Neuron |
| Lymphatic system | Category:Lymphatic system | The ABO blood system and rhesus blood system | Blood type |
| Lymphatic system | Lymphatic system | The ABO blood system and rhesus blood system | Category:Blood antigen systems |
| Main groups of animals | Animal | The ABO blood system and rhesus blood system | Rh blood group system |
| Menstrual cycle | Category:Menstrual cycle | The brain and spinal cord | Brain |
| Menstrual cycle | Menstrual cycle | The brain and spinal cord | Category:Brain |
| Mutations | Category:Mutation | The brain and spinal cord | Category:Central nervous system |
| Mutations | Mutation | The brain and spinal cord | Category:Spinal cord |
| Nervous system | Category:Nervous system | The brain and spinal cord | Spinal cord |
| Nervous system | Nervous system | The placenta | Placenta |
| Nutrient cycles in an ecosystem | Nutrient cycle | Tissue respiration | Respiration (physiology) |
| Nutrition in humans | Human nutrition | Transpiration | Transpiration |
| Organ transplants | Category:Organ transplantation | Transport in plants | Active transport |
| Organ transplants | Organ transplantation | Tropisms | Category:Tropism |
| Organisms and their environment | Organism | Tropisms | Tropism |
| Other applications of genetic engineering | Genetic engineering | Types of immunity | Category:Immunology |
| Photosynthesis | Category:Photosynthesis | Types of immunity | Immunity (medical) |
| Photosynthesis | Photosynthesis | Vaccination | Category:Vaccines |
| Plant and animal communities in aquatic and terrestrial ecosystems | Category:Biodiversity | Vaccination | Vaccination |
| Plant biology | Botany | Variations among organisms | Genetic variation |
| Plant biology | Category:Botany | vertebrates | Vertebrates |
| Plant diversity | Biodiversity | Worm infestations | Category:Parasites |
| Plant structure and functions | Category:Plant anatomy | Worm infestations | Parasitic worm |

*Notes:* See Section 3 and Appendix A for additional details.

Supplementary Table S6: Most Popular Syllabus Topics by Hours Spent Browsing

| Subject | Syllabus Topic | Hours Per Student |
|---|---|---|
| | NA | 22.3121 |
| Biology | Genetics and evolution | 0.2458 |
| Social Studies | African Culture | 0.2221 |
| Life Skills | Components of sexuality | 0.2133 |
| Social Studies | Constitution of the Republic of Malawi | 0.1618 |
| Biology | ADH and osmoregulation | 0.1523 |
| Chemistry | Chemical bonding and properties of matter | 0.1513 |
| English | MacBeth (play) | 0.1450 |
| Physics | Mechanics | 0.1442 |
| Life Skills | Sexual productive health and human behaviour | 0.1429 |
| Biology | Process of birth | 0.1417 |
| Chemistry | Elements and the periodic table | 0.1355 |
| English | The Pearl (novel) | 0.1206 |
| Physics | Heat transfer | 0.1049 |
| History | Origins of Christianity and Islam | 0.0998 |
| Biology | Circulatory system | 0.0968 |
| Chemistry | Chemical composition of matter | 0.0964 |
| History | Patriotism and nationalism | 0.0956 |
| Agriculture | Agricultural research | 0.0911 |
| Biology | Abnormal conditions associated with reproduction | 0.0849 |
| Biology | Plant biology | 0.0849 |
| Chemistry | Chemical bonding | 0.0791 |
| Geography | The solar system | 0.0781 |
| English | Romeo and Juliet (play) | 0.0780 |
| Social Studies | Development | 0.0743 |
| Biology | Endocrine system | 0.0724 |
| Social Studies | Nationalism and independence movement in Africa - Malawi | 0.0723 |
| Chemistry | ADH and osmoregulation | 0.0642 |
| Biology | The brain and spinal cord | 0.0636 |
| Social Studies | The Ngoni | 0.0619 |
| Geography | Climatic regions and world vegetation (biomes) | 0.0601 |

*Notes:* See Section 3 and Appendix A for additional details.