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Science & Society

Value of Electronic Educational Media in Combatting Parasitic Diseases

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Parasitic diseases have plagued mankind throughout history, and even today parasites continue to cause disease, disability and death in millions of people worldwide. Targeted electronic educational media for bringing awareness to local inhabitants of endemic communities, including public health practitioners, are vital tools in the battle against parasitic diseases.

Parasitic Diseases – Still Neglected

Parasitic diseases have plagued mankind since prehistoric times. From malaria parasites identified in 30-million-year-old amber-preserved mosquitoes [1], to calcified Guinea worms found in ancient Egyptian mummies (ca. 1000 BC), to porcine cysticercosis references in Aristophanes' Ancient Greek plays (ca. 380 BC) [2], our history has been riddled with parasites.

Even today, neglected parasitic diseases cause disability and death in millions of people, particularly in low- and middle-income countries (LMICs) across sub-Saharan Africa (SSA), Latin America, and Asia. Malaria is a recognizable scourge of humankind, causing an estimated 216 million cases and 445 000 deaths annually, predominantly in SSA[i]. Meanwhile, many lesser-known parasites also wreak havoc across the globe. Over 56 million people are estimated to be infected with one of the foodborne trematode worms responsible for causing severe lung and liver disease, some of which can cause fatal bile duct cancer [3]. As well as the substantial health problems caused by parasitic infections, there are also heavy economic burdens associated with medical costs and productivity losses in symptomatic patients. The direct costs of Chagas' disease, caused by the protozoan parasite *Trypanosoma cruzi* that infects over 7 million Latin Americans, was estimated at over US$7 billion per year, while treatment for an episode of sleeping sickness, caused by another *Trypanosoma* species found in SSA, can cost rural households in the Democratic Republic of Congo up to 40% of their annual income [4].

Many parasites are zoonotic and are transmitted to man by direct animal contact, by meat/fish consumption, or through the environment. Besides their public health impact, foodborne parasites may also cause substantial economic losses to the animal sector. *Taenia solium*, the pork tapeworm, is the leading cause of acquired epilepsy in endemic areas, but is also a cause of condemnation of infected pork. In China alone, an estimated 200 million kilograms of cystic pork is discarded, representing a loss of more than US$120 million, every year [5].

In the first World Health Organization (WHO) report on Neglected Tropical Diseases (NTDs) in 2010, Director General Margaret Chan stated that the NTDs can be controlled and even eliminated with concerted global action. In 2013 the World Health Assembly passed a resolution calling for member states to recognize and support the implementation of the 2012 WHO roadmap 'Accelerating work to overcome the global impact of neglected tropical diseases' in order to alleviate and, where possible, put an end to the misery cause by ancient diseases of poverty [4].

Despite these resolutions, and despite the many advances in parasite diagnostics and treatments and the countless dollars spent on global parasite control programs in recent decades, the war on parasitic diseases is still far from being won.

The Power of Education

> 'Education is the most powerful weapon that you can use to change the world.' – Nelson Mandela

Ignorance is a major contributor to parasite transmission. The life cycles of many parasitic zoonoses are complex, and the links between different hosts, human behaviors such as open defecation, specific consumption habits, or freshwater swimming, and the development of clinical signs, which may manifest years after infection, are not easily recognizable. Studies have shown that health education can cause powerful and cumulative improvements in knowledge, attitudes and practices that can reduce parasite transmission and disease occurrence in endemic communities, especially when implemented alongside treatment programs and other specific control measures [6].

Why Electronic Media?

The rate of scientific advancement is such that the compendium of human knowledge is doubled every 8–10 years [7]. Unlike traditional teacher-based education, electronic-based tools provide a platform for standardized educational messages that can more easily be adapted and updated as needed. They can reduce training costs and be widely disseminated, even to remote areas with low teacher coverage. Their interactive audiovisual nature tends to make the learning experience more effective and enjoyable than text-only methods [7], and can also benefit illiterate users.

From a user perspective, electronic educational media allow individuals to learn at their own pace and according to their specific learning needs. Computer programs, apps for smartphones and tablets, and web-based media enable learning anywhere, anytime. Weaker and stronger students can benefit from the addition of remedial or advanced modules, respectively.

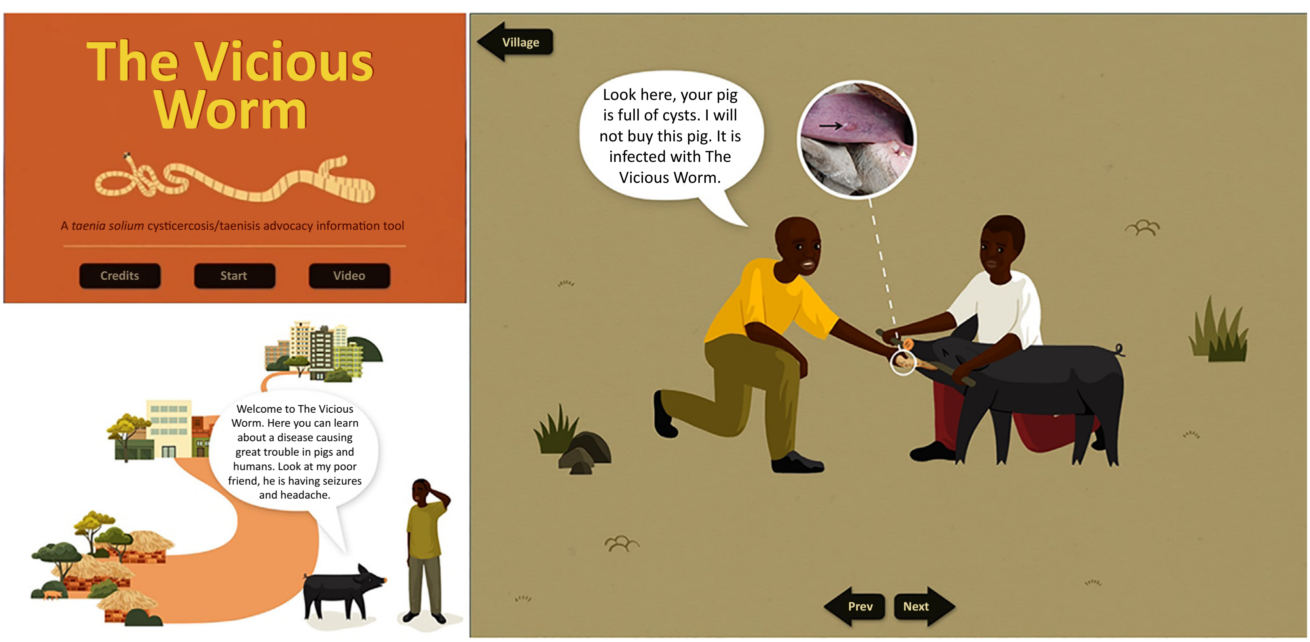
Currently, mobile networks cover 95% of the global population, and almost 70% of the 4.7 billion individual subscribers live in LMICs [8]. While access to computers, internet-enabled devices, and data networks can be variable and sometimes prohibitively expensive, ongoing development is expected to reduce these obstacles. Sponsors such as telecommunication providers and Google may provide students with free network access to educational websites or learning apps[ii].

Targeted Electronic Education in Action

Electronic educational tools have been developed for the targeted education of communities affected by parasitic diseases. *The Vicious Worm*, for example, is a freely-downloadable computer program[iii] for education about the pork tapeworm. It uses cartoons, videos, and quizzes to provide comprehensive information in a fun and interactive way, set within an illustrated SSA context (Figure 1). Studies have shown that *The Vicious Worm* is effective for increasing knowledge and awareness in Tanzanian medical and veterinary professionals [9] and Zambian primary school students [10]. *The Vicious Worm* is available in both online and app forms; it has recently been translated into Kiswahili, and other translations are in the pipeline to further expand its reach throughout SSA [11].

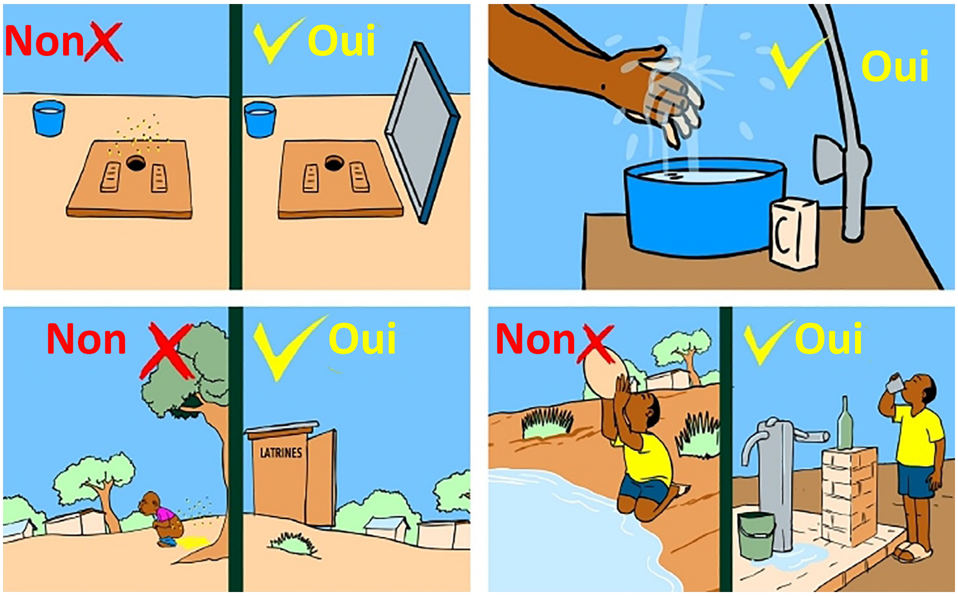
Short animated cartoons for education about parasitic worms and diarrheal diseases have been trialed in school-aged children in China (*The Magic Glasses*[iv]) and Côte d'Ivoire (*Koko et les lunettes magiques*[v]) (Figure 2). The cartoons were shown to be effective at increasing short-term knowledge, and were reportedly liked by students and teachers [12]. In the Chinese study, parasitic worm infection rates halved (8.4–4.1%, P <0.0001), and observed occurrence of handwashing increased from 54% to 98.9% (P <0.0001) in the intervention group compared to the control group [13].

Other electronic educational media include interactive talking books, DVDs, and songs, such as those used to educate



Trends in Parasitology

Figure 1. Screenshots from *The Vicious Worm*[iii]. This interactive computer program is used in sub-Saharan Africa for education about the pork tapeworm. These screenshots show two introductory screens and a scene from the village in which a pig owner and trader inspect a pig's tongue for cysts or 'the vicious worm'.



Trends in Parasitology

Figure 2. Extracts from *Koko et les lunettes magiques*[v] [12]. This animated cartoon has been used in Côte d'Ivoire to educate school children about parasitic worms and diarrheal diseases. These images show the final part of the cartoon, where key educational messages are reinforced.

Indigenous communities about dog- and cat-associated zoonoses in rural areas of northern Australia[vi], and local communities about *Opisthorchis viverrini* in Thailand [6]. Tablet-based educational interventions have also been successful at raising awareness and changing behaviors for prevention of other, non-parasitic diseases, including cervical cancer and human papillomavirus infections [14].

Of course, the scope of electronic learning media extends far beyond community education. Directing educational content at public health students and professionals, as well as community leaders and extension workers, enables greater dissemination of educational messages by 'training the trainers'. E-learning has already been incorporated into higher educational and public health curricula across many disciplines worldwide, with studies suggesting that students using computer-aided learning develop knowledge and skills 30% faster than those using traditional textbook-based methods [7].

Future Directions

As technology continues to advance, we must ensure that we make full use of these developments to disseminate messages of public health importance in an effective and efficient way. Increasing network connectivity and smartphone saturation should be ensured to bring new learners into the educational sphere. Our scientific, evidence-based educational messages must rise above the false information and 'fake news' so prevalent in today's web-based society. High-quality educational messages, translated into appropriate language for target audiences, can be developed as easily-adaptable electronic media for worldwide dissemination. Engaging and educating students, public health professionals, and communities via computer-based programs, games, animated cartoons, songs, and other media can increase awareness of parasitic diseases and promote behavioral change: vital strategies for mankind's battle against parasites.

Resources

[i] www.who.int/news-room/fact-sheets/detail/malaria
[ii] https://techfinancials.co.za/2017/09/27/siyavula-digital-learning-platform-gets-r20-million-google-org/
[iii] https://theviciousworm.sites.ku.dk/
[iv] www.qimrberghofer.edu.au/magic-glasses/
[v] www.youtube.com/watch?v=PCNLEK5Ityw
[vi] www.amrric.org/resources/view/787

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Spotlight

para-Aminobenzoate Synthesis versus Salvage in Malaria Parasites

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Enzymes of the folate *de novo* synthesis pathway in malaria parasites are proven antimalarial drug targets. A key precursor for folate synthesis is *para*-aminobenzoate (*p*ABA). In a recent study [1] (*Cell Rep.* 2019;26:356–363 e4), the contributions of *p*ABA synthesis versus salvage were re-evaluated in a rodent malaria model with knockout parasites grown in mice fed with various diets. The results imply that malaria parasites can either synthesize or salvage *p*ABA to meet the demand for folates.

Folates, derived from the Latin word *folium* (leaf), are abundant acids in green leaves and grain products, and are also concentrated in certain animal tissues (e.g., liver and kidney). Folates are central cofactors in one-carbon metabolism that are essential for synthesizing nucleic acids (thymidine and purines), methionine, and mitochondrial *N*-formyl-methionyl-tRNA [2,3]. Not only does folate cure megaloblastic anemia and prevent neural tube defects in fetuses, it also has beneficial effects in other health conditions [3]. While humans are folate auxotrophs, malaria parasites are able to synthesize it *de novo*. The folate biosynthesis pathway has been successfully exploited to yield a long list of antimalarial drugs targeting dihydropteroate synthase (DHPS) or dihydrofolate reductase-thymidylate synthase (DHFR-TS), two enzymes of this pathway [4]. For instance, for a long time sulfadoxine (a DHPS inhibitor) and pyrimethamine (a DHFR inhibitor) have been used in combination to prevent or treat falciparum malaria [5]. A key precursor for the synthesis of folate is *p*ABA (Figure 1), which could be derived either from *de novo* synthesis or salvage. Yet, the relative contributions of *p*ABA synthesis and salvage in malaria parasites have remained unsettled.

In 1952, Maegraith *et al.* observed that rats fed with milk were significantly less susceptible to *Plasmodium berghei* infections [6]. Shortly after, it was found that lack of *p*ABA was the main reason for poor parasite growth in animals on a milk diet [7]. Since then, it has been generally accepted that *p*ABA salvage from foods is the key to support parasite growth *in vivo*, and the putative *p*ABA *de novo* synthesis pathway from the precursor chorismate via two enzymes, aminodeoxychorismate synthase (ADCS) and aminodeoxychorismate lyase (ADCL), has been left uncharacterized. In the work just published by Matz *et al.* [1], the authors deleted ADCS and ADCL individually in *P. berghei* and observed that both knockout (KO) parasite lines were able to propagate normally in mice fed with a conventional fortified diet. For the first time, Matz *et al*. have provided clean genetic data showing that *p*ABA *de novo* synthesis is not essential for malaria parasites grown in animals with normal diets. In milk-fed mice, both ADCS and ADCL KO parasites suffered a severe growth arrest, which was abolished upon *p*ABA supplementation. Thus, *p*ABA salvage is sufficient to support parasite growth in mice fed normally, rendering *p*ABA *de novo* synthesis not essential under these conditions. One thing remaining to be clarified, however, is why KO parasites did not succumb completely in mice fed with milk alone, when both dietary *p*ABA and *de novo* synthesis were eliminated simultaneously. Although, with a lower parasitemia (sometimes undetectable), the ADCS KO parasites remained persistent in milk-fed mice for an extended time [1]. The authors reasoned that parasites might be able to salvage alternative precursors or folates to some degree. While milk contains a considerable concentration of 5-methyltetrahydrofolate (5-MTHF) [1], this compound is taken up very poorly by malaria parasites, but, in line with the authors' suggestion, *p*ABA monoglutamate, one of the degradation products of 5-MTHF, has been shown to be a reasonably good substrate for the