KNOX GRAMMAR SCHOOL

STATE

DA VINCI DECATHLON 2018

CELEBRATING THE ACADEMIC GIFTS OF STUDENTS IN YEARS 7 & 8

da Vinci Decathlon® EXCITE ENRICH CHALLENGE An initiative of Knox Grammar School

IDEATION

TEAM NUMBER _____

1	2	3	4	Total
/15	/15	/15	/15	/60

IDEATION

VANISHING ACT

BACKGROUND AND PROBLEM

In January of 2018, global confectionary superpower **Mars** warned that by the year 2020, demand for **chocolate** will exceed supply. This is not only due to the extraordinary and ever-growing popularity of the product, but also because of the risks posed to **cacao crops** by the environmental effects of **climate change.** Rising temperatures ultimately result in the shrinkage of rainforests, which are the natural environment of cacao trees, and it could therefore be only a few years before we face a **shock** chocolate deficit.

As perhaps the most adored of all foods, this **unexpected** news has obviously been met with fear and panic by millions worldwide. Fortunately, though, it has also catalysed **action** by individuals and corporations alike. For example, Mars have committed $1,000,000,000 to **sustainability** efforts, through methods such as forestation, education for farmers and the genetic development of a more resistant cacao seed.

Scientists predict that if measures such as these are not fervently pursued, the world could face an extreme chocolate shortage by **2050.** This surely would be apocalyptic. So, how should we proceed?

THE DESIGN CHALLENGE

Your task is to **develop** a **solution** to the current cacao shortage facing the world. You may take the perspective of a **one** of a number of different stakeholders, such as:

- Chocolate companies;
- Government;
- Farmers;
- Environmental bodies;
- Scientists, inventors and researchers;
- Economists;
- World bodies such as the UN or World Trade Organisation.

Similarly, you have a wide variety of options when it comes to the nature of your solution. While it could be a technological **invention**, it could also be a government **policy,** a result of scientific **research** and development, some other physical **product,** or anything else!

Also, keep in mind that you do not have to address the issuing by **directly** ensuring the sustained growth of cacao crops (although this is certainly one way of tackling the problem) – you might instead want to create some **alternate consumer product,** or indirectly address issues such as **climate change, deforestation** or **crop disease** instead. Try to think of a solution which although inspired by the information above and the stimulus materials provided, is fundamentally different and **original.**

It is important that you present a solution which displays a high degree of **creativity** and **innovation** yet is also **realistic** and **relevant** to the current and future needs of individuals and society. Moreover, the solution should be **detailed** and have **long-term** effects; a stop-gap answer will not be enough!

Stimulus material to assist in your solution is attached at the end of this paper.

Please **carefully read** the marking criteria on the following pages for additional guidance on what to include in the answer templates provided, and where to do so. You will have **ninety (90) minutes** to complete the four components below. You will be provided with templates on which to complete your answers.

EMPATHISE (Ethical Decision-Making Framework) (15 marks)

This involves evaluating what 'ought to be done', through considering rights, obligations, fairness, the benefits and detriments for societies and other virtues. Reaching a final decision involves a degree of conviction and belief in what is 'the right thing to do'.

DEFINE (Design Brief) (15 marks)

Here, you must identify the problem, outline the ethical issues, evaluate the challenges and research findings, and identify potential solutions.

IDEATE (Reflection) (15 marks)

You must then reflect on their solutions and whether they will be viable. A preferable solution should be identified, and any unanswered questions should be addressed. Issues of implementation are also crucial to reflect upon.

CREATE (Prototype) (15 marks)

Finally, a design for how your ideas and solution will be disseminated must be produced. This could be a story-board, mind-map, diagram, model, narrative or any other appropriate medium. Critically, an audience must be able to understand the process of dissemination by examining this prototype.

MARKING GUIDELINES

1. Ethical decision-making framework (15 marks)

QUESTIONS	LIMITED	SOUND	OUTSTANDING	TOTAL
1: At least two facts	0	1	2	
2: Identifies challenges	0	1	2	
3: States why it matters	0	1-2	3	
4: Identifies negative consequences	0	1	2	
5: Identifies positive consequences	0	1	2	
6: Demonstrates empathy	0	1	2	
7: Identifies community concerns	0	1	2	
			TOTAL	/15

2. Design Brief (15 marks)

ASPECT	LIMITED	SOUND	EFFECTIVE	OUTSTANDING	TOTAL
Ideate: What – why it matters, challenges, ethical issues & the vision	0-1	2-3	4	5	
Research: Why-findings that support ideas and solutions	0-1	2-3	4	5	
Solutions: How – originality, diversity and overall quality of possible solutions	0-1	2-3	4	5	
				TOTAL	/15

3. Reflection (15 marks)

ASPECT	LIMITED	SOUND	EFFECTIVE	OUTSTANDING	TOTAL
Ideation: Ideas	0-1	2-3	4	5	
Implementation: Who, what and how?	0-1	2-3	4	5	
Dissemination: how to succeed with the solution	0-1	2-3	4	5	
				TOTAL	/15

4. Prototype (15 marks)

ASPECT	LIMITED	SOUND	EFFECTIVE	OUTSTANDING	TOTAL
Originality and creativity	0-1	2-3	4	5	
Clarity and communication of ideas	0-1	2-3	4	5	
Detailed and realistic long-term solution	0-1	2-3	4	5	
				TOTAL	/15

TOTAL: /60

ADDITIONAL STIMULUS

M&M's maker fears chocolate shortage by 2050, report says

By Josh Hafner, 2 January 2018, USA Today

Retrieved from https://www.usatoday.com/story/money/nation-now/2018/01/02/m-ms-maker-fears-chocolate-shortage-2050-report-says/996962001/

The world's chocolate supply could melt into a shortage within a few decades, and the maker of M&M's, Snickers and Twix hopes scientists can save humanity's sweetest invention.

Rising temperatures from climate change threaten to shrink the slim strip of rainforests around the equator where the cacao trees used to make chocolate thrive, according to a 2016 review from the National Oceanic and Atmospheric Administration (NOAA). And the two West African nations that produce over half of the world's chocolate — Ghana and Ivory Coast — would feel the heat.

"By 2050, rising temperatures will push the suitable cacao cultivation areas uphill," the article found, doubling the altitude needed for prime cacao production in the two nations. In nations like Ghana, moving cacao farming to higher ground could mean disrupting natural habitats and protected reserves.

That's why candy maker Mars pledged $1 billion last September toward sustainability efforts aimed at saving chocolate, *Business Insider* reports, with the corporation recruiting University of California researchers to develop a sturdier cacao plant that won't wilt in drier climates.

It all could come down to CRISPR, a tool developed by UC Berkeley geneticist Jennifer Doudna that lets scientists tinker with DNA strands to potentially alter anything from produce to people. Already, genome researcher Myeong-Je Cho is growing cacao seedlings at the university that may let cacao farms stay put even as environmental shifts occur, according to the report.

Warnings of chocolate's precarious future aren't new: Years ago, Mars cautioned that consumer demand for cocoa would exceed supply by 2020, creating a chocolate deficit. Some at the time, including the International Cocoa Organization, called such doomsday predictions overblown.

However dire chocolate's state, the researchers whose work predicted the 2050 conditions signalled hope that the industry could change.

"These changes in climatic suitability are predicted to take place over a time period of almost 40 years, so they will mostly impact the next rather than the current generation of cocoa trees and farmers," Peter Läderach and his co-authors said in a 2013 study.

"In other words, there is time for adaptation."

The Race to Save Chocolate

By Howard Schmitz (CEO of Mars), Howard-Yana Shapiro, 1 June 2015, Scientific American

Retrieved from https://www.scientificamerican.com/article/the-race-to-save-chocolate/

To the ancient Mayans, it was the food of the gods. Nineteenth-century Cubans used it as an aphrodisiac. In the 20th century, American culinary authority Fannie Farmer recommended its “stimulating effect” for “cases of enfeebled digestion.” Throughout history people have prized cocoa—the defining ingredient of chocolate—a tradition that endures in our modern era. This past Valentine's Day alone, Americans dropped an estimated $1.7 billion on chocolate. Around the world people spend more than $98 billion a year on the treat. And with appetite on the rise thanks to expanding population size and growing numbers of people in the developing world who can afford chocolate, demand may outstrip supply in the near future.

All this cocoa production does more than feed our collective sweet tooth: the five million to six million farmers in the tropics who cultivate the cacao trees from which cocoa is produced rely on the sales of the seeds to feed themselves and their families. Workers extract the seeds (often called beans) from football-shaped pods and then ferment and dry them to form cocoa liquor, butter and powder. Roughly 50 million livelihoods depend on the long production road the cacao seeds travel from farm to candy on store shelves. In Ivory Coast, source of 40 percent of the world's cocoa, such farming accounts for a full 15 percent of GDP and employs 5 percent of households.

“Many of these farmers use their cacao trees like ATM machines. They pick some pods and sell them to quickly raise cash for school fees or medical expenses. The trees play an absolutely critical role in rural life,” observes Peter Läderach of the International Centre for Tropical Agriculture, who has led research into the effects of climate change on cacao farming in Ivory Coast and Ghana. Along with Nigeria and Cameroon, those countries produce 70 percent of the world's cocoa supply.

But the delicate “chocolate tree,” *Theobroma cacao*, is in peril. The tree has always been extremely susceptible to pests and fungal infections. In 1988, just six years after Mars, Incorporated (our employer), established its Centre for Cocoa Science in the thriving cacao-growing region of Bahia, Brazil, the fungal disease witches' broom was found in the area. It reduced production by 80 percent, driving people whose families had grown cacao for generations to abandon their farms and move to city shantytowns—effectively destroying in a few short years a vast archive of cacao-farming knowledge built over centuries. Now another fungal disease, frosty pod rot, has spread throughout Latin America and may soon arrive in Brazil, where it could be even more devastating than witches' broom. And what would happen if witches' broom were introduced into West Africa, either by accident or in an act of bioterrorism?

Making matters worse, many farmers, particularly those in Africa, struggle to obtain the best seeds, fertilizers and fungicides, as well as training in their use. Yields—and the income they generate—are thus a third or less of their potential. Meanwhile the world clamours for more cocoa: manufacturers reckon the industry now produces around 4.4 million metric tons of cocoa; by 2020 they expect that demand will outstrip supply by one million metric tons.

In view of the challenges, we and others in the chocolate industry worry that without fast action on a number of fronts, cacao farming could slide into a downward spiral. To that end, researchers are currently working to find ways to multiply yields sustainably. Some of the efforts involve non-traditional collaboration among farmers, corporations, universities and government agencies, including the U.S. Department of Agriculture. One such collaboration, led by Mars, has sequenced the cacao genome in an attempt to find ways to breed hardier trees. Whether these efforts will succeed in raising yields enough to save the livelihoods of farmers and meet the world's passion for chocolate remains to be determined, but we see some encouraging signs.

The assault on cocoa

Cacao farmers certainly feel the pressure to increase yields, but the crop is hard to grow. The cacao tree originated in the upper Amazon, in what is now Ecuador, and was imported into the Mexican empire of the Olmec, who domesticated it and then sent it to the Mayans and Aztecs. Portuguese and Spanish sailors took the tree to colonies in Africa and Asia. Today the cacao tree still grows only in a narrow band within about 18 degrees north and south of the equator. It prefers rich, well-drained soils, which are often scarce in the tropics. And it requires heat and humidity, which lead to fungal, viral and pest problems that claim up to 40 percent of the crop. Besides witches' broom and frosty pod rot in the Americas, other threats to the tree include cocoa swollen shoot virus in West Africa and a moth called the cocoa pod borer in Southeast Asia, the latter often costing $600 million in crop losses a year. Ghana's cacao trees suffer insect damage, black pod rot, water mould and the swollen shoot virus. Experts fear that these scourges are now attacking the healthier trees in neighbouring Ivory Coast. We worry that Africa or Asia could suffer a Brazil-like collapse because of these threats.

The limited genetic variation of the tree does not help matters. Mars cacao geneticist Juan Carlos Motamayor and his collaborators found through genetic tracing that cacao comes in 10 different major varieties, all of which belong to the same single species. Thus, although the similarity among strains means that growers can crossbreed them easily, it also means that the collected strains do not contain enough variation to provide much natural resilience to pests and disease; if one strain is genetically susceptible, chances are good they all will succumb. When farmers save their own seeds to plant new trees, this local inbreeding leaves the trees even more susceptible to pests and fungi.

Beyond the usual difficulties, growing conditions seem to be getting worse. Weather extremes such as floods, droughts and windstorms have always made farming in the tropics difficult. Climate change is beginning to intensify these extremes, which could worsen pest and disease infestation and disrupt water supplies. The 2007 report of the Intergovernmental Panel on Climate Change predicted that by 2020 yields in Africa from rain-fed crops—which make up the vast majority of African crops, including cacao—could be reduced by up to 50 percent in some countries. The same report predicted increases in temperature and associated decreases in freshwater in Amazonia by mid-century. Furthermore, Läderach's research on the effects of climate change in Ghana and Ivory Coast predicts that the ideal cacao-growing areas will shift to higher altitudes to compensate for rising temperatures. “The problem is that much of West Africa is relatively flat, and there is no ‘uphill,’” he commented in a September 2011 press release. Climate shifts could thus lead to drastic decreases in terrain suitable for cacao crops. In Indonesia, meanwhile, the annual monsoon rains are

becoming more intense over shorter periods, often knocking the flowers off the cacao trees, thereby preventing pod formation.

Poverty exacerbates these challenges. In Ivory Coast and Ghana, internal movement of people of various ethnic origins and immigration from poorer, neighbouring Burkina Faso have not only created tensions between richer and poorer people but also muddied property rights. In both countries, farmers hesitate to invest in trees that their children may not inherit, and many do not want to continue cacao farming unless tree productivity can be significantly improved. Young people are moving out of the cacao-growing areas, which translates to an increase in the average age of farmers and a decrease in their education levels.

Unfortunately, fertilizers, fungicides and pesticides—the most effective ways to significantly boost crop production—are rarely used in the region because farmers cannot afford them and do not know how to employ them effectively. Even if they could afford these tools, the remote locations of the farms, which are often accessible only via poorly maintained roads, mean governments and merchants have a hard time delivering these products to farmers and providing education on how best to use them.

Saving chocolate

Because the threats to cocoa production come from pests, disease, climate change and poverty, work must be done on all these issues to raise yields without tearing down rain forests to gain arable land. Abandoned land must be rehabilitated by enriching the soil with fertilizer and by planting trees and shrubs to control erosion. Whereas the average global yield is about 460 kilograms of cacao beans per hectare, crops tended using modern farming techniques could easily yield 1,500 kilograms or more per hectare. For many cacao farmers in developing nations, tripling their yields would mean the difference between a subsistence-level income of $1 a day and a manageable $3 a day.

Science took a critical step toward raising yields about five years ago, when researchers from Mars, the USDA's Agricultural Research Service (ARS), IBM and other institutions sequenced and analysed the genome of the so-called Matina 1-6 variety of *T. cacao*, which many experts consider to be the progenitor of 96 percent or more of all the cacao grown in the world. We then made the results freely available to all—including Mars's competitors—over the Internet because we felt no single organization has the resources to, in a timely manner, do the breeding work needed to save the species from the various crises it faces. Cacao has not received the genetic attention paid to commodities such as rice, corn and wheat—attention that has dramatically improved yields for these crops. (Another consortium, led by the French agricultural research organization CIRAD, announced its sequencing of a different variety of cacao shortly after we released our sequence.)

To be effective, the molecular research on cacao taking place in labs in the developed world has to connect to what breeders are doing on the ground in the developing world. Mars and the ARS have thus, over the past decade, organized networks of cacao breeders in West Africa, Southeast Asia and Latin America. The breeders are using the cacao genome to discover where, among the world's cacao crops, disease resistance, enhanced yields, water and nutrient use efficiency, and climate change adaptability are to be found.

Thanks to such collaborations, when Wilbert Phillips-Mora, a breeder in Costa Rica, found a cultivar that exhibited some resistance to frosty pod rot, he sent samples to the molecular biologists in the network, who were then able to use the genome map to identify the gene variant in the cultivar that confers resistance to the dread fungus. In subsequent breeding

efforts, the breeders can quickly determine if new cultivars carry that trait or other useful traits for the next generation of cacao trees. Already farmers in Latin America are grafting parts of branches from these new plants to their trees.

Breeders have previously identified cultivars that resist witches' broom, but they do not produce high-quality cocoa. The new breeding work raises the prospect of mixing such desired attributes as resistance and quality in a single *T. cacao* cultivar through careful crossbreeding. In a similar vein, researchers have discovered a type of cacao resistant to Southeast Asia's vascular-streak dieback disease and are currently analysing the genetic underpinnings of that trait. Cacao experts ultimately hope to breed trees that are resistant to other fungi and pests and that can endure the heat and water scarcity that often accompany climate change while preserving the quality of the cocoa beans.

Researchers also aim to produce shorter trees. During harvest, farmers cut the cacao pods from the tree with knives on the ends of long poles. They take great care to not damage the site of pod growth. A shorter but equally or more productive tree would require fewer resources to generate the pods and be easier to harvest.

Yet even short, drought-tolerant trees still need some water. Eventually, no matter how efficient our cultivars, cacao growers will have to figure out how to irrigate more crops instead of relying on fickle rainfall. Farmers, scientists, aid agencies and foundations are trying different approaches to solving this problem across regions. Brazil is working on two radically different strategies. In the first, small farmers are trained to develop mixed agroforestry systems, in which cacao trees are planted among food crops, fodder trees and timber trees. These mixes improve water-holding capacity throughout the entire system by varying the root structures throughout the matrix of trees. The second strategy takes the opposite tack, creating large plantations of cacao trees in Bahia, Brazil, at higher altitude—out of the traditional pest and disease ranges—in the full sun and irrigating them with fertilizer-enriched water for maximum productivity. Vietnamese growers—some of whom are encountering falling water levels as a result of unsustainable groundwater use—are making reservoirs to collect rainwater for irrigating the cacao trees.

As is the case for water supplies, each cacao-growing region of the world has its own set of challenges and organizations that are stepping up to tackle them. In early 2009 the World Cocoa Foundation (WCF) began a $40-million program, funded by the Bill & Melinda Gates Foundation and 17 companies, to improve the livelihoods of cacao farmers in five West and Central African countries. By 2014 the Cocoa Livelihoods Program had trained nearly 200,000 farmers, working with them to enhance productivity and quality, promote crop diversification and boost supply-chain efficiency.

The program is based on a successful series of WCF field schools for African cacao farmers, themselves modelled on similar United Nations Food and Agriculture Organization farmer field schools. School facilitators found local farmer leaders to do much of the teaching, and aside from covering obvious topics such as disease management, pruning and harvesting, the schools tackled topics such as malaria, HIV/AIDS, farm safety and the avoidance of child labour. According to WCF president Bill Guyton, graduates increased their incomes by 23 to 55 percent.

In Southeast Asia, farmers tend to get the training they need because of better extension services. The main hurdle there is to develop integrated pest-management techniques to deal with the devastating pod borer—work that has begun but still has a long way to go.

Such techniques include using pheromone-based traps and black ants (natural enemies of the pod borer) to control the moths and not relying solely on pesticides, which could damage the biodiversity in the region.

Tripling cacao yields sustainably is perfectly possible. Effective fertilizers, fungicides and training programs already exist, and scientists are beginning to develop cultivars resistant to some of the problems that have long dogged the cacao tree. But getting all these resources to poor, remote farmers so that they can become better off and better connected is a job too big for any single government, U.N. agency, company or project. Meeting that objective will take innovative, energetic coalitions. We are optimistic that a more secure future for chocolate and the vast social, cultural and ecological ecosystem it supports will come to pass, but it must be said that making cacao a truly sustainable crop will be a grand challenge indeed.