Applied Chemistry in STEM Education

Placing chemistry into a real-world context

"Facilitating Experiential & STEM Learning Opportunities"

Organized and Hosted by Hua Quan Village and Sino-Exchange

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By: Scott A. Campbell

September 22nd-24th

STEM 教育中的应用化学

将化学置于现实世界中

主办促进体验式和 STEM 学习机会

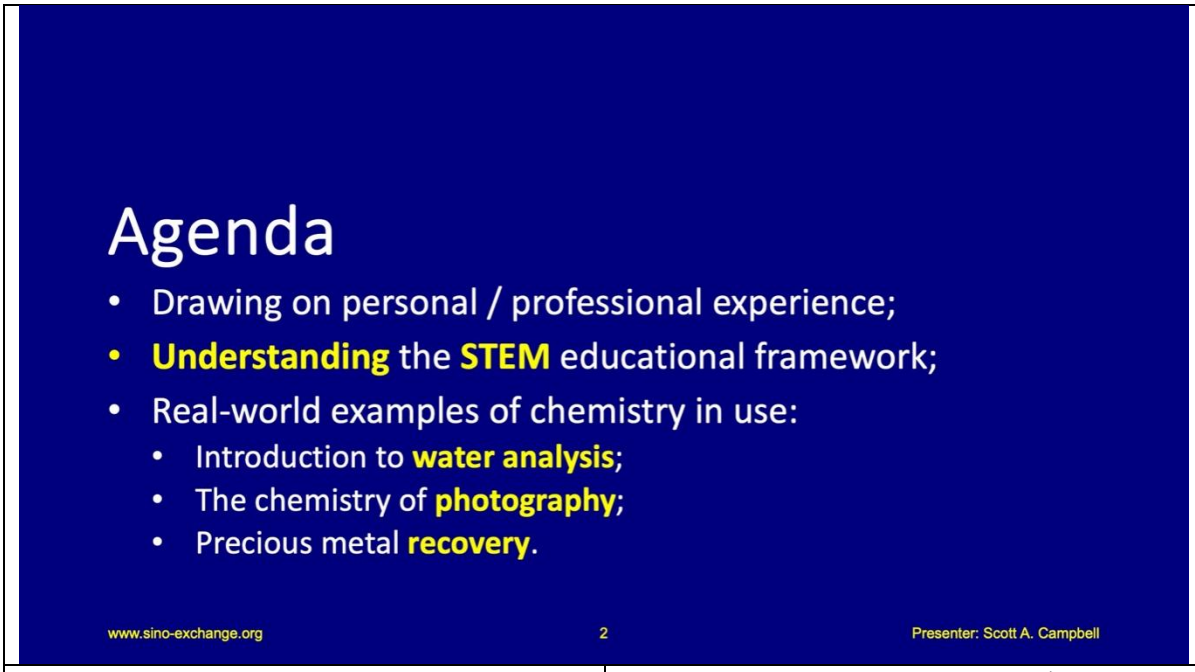
由华泉小村、中外合作交流

在华泉小村举办

作者：胡屹龙

9 月 22 日-24 日

Welcome to this presentation of ***Chemistry in STEM***. In this presentation we will look *at different ways to solve real-world problems in the context of STEM education.*	欢迎收看 STEM 化学讲座。在本次演讲中，我们将探讨在 STEM 教育背景下解决现实世界问题的不同方法。



So, let me quickly review what we are going to cover in today's presentations.

First, I would like to share with you some of my personal experiences from when I was working in industry, and I will use these experiences as foundation for designing chemistry labs that would place scientific theory into an appropriate real-world context.

Second, I would like to talk a little bit about what STEM as is always a lot of confusion surrounding the true nature of STEM education.

Next, I would like to give you some real-world examples of chemistry in use that you can use to design authentic chemistry labs with. These examples will include:

- How to conduct a water analysis using the same methods as a health and safety lab technician uses.
- The use of chemistry in photography, and this is a great way to create cross-circular lessons that will create rigorous academic learning outcomes while also including the arts.
- And finally, how we can recover precious metals such as gold from e-waste.

因此，让我快速回顾一下我们今天要讲的内容。

首先，我想与大家分享我在工业界工作时的一些个人经历，我将利用这些经历作为设计化学实验室的基础，将科学理论置于适当的现实环境中。

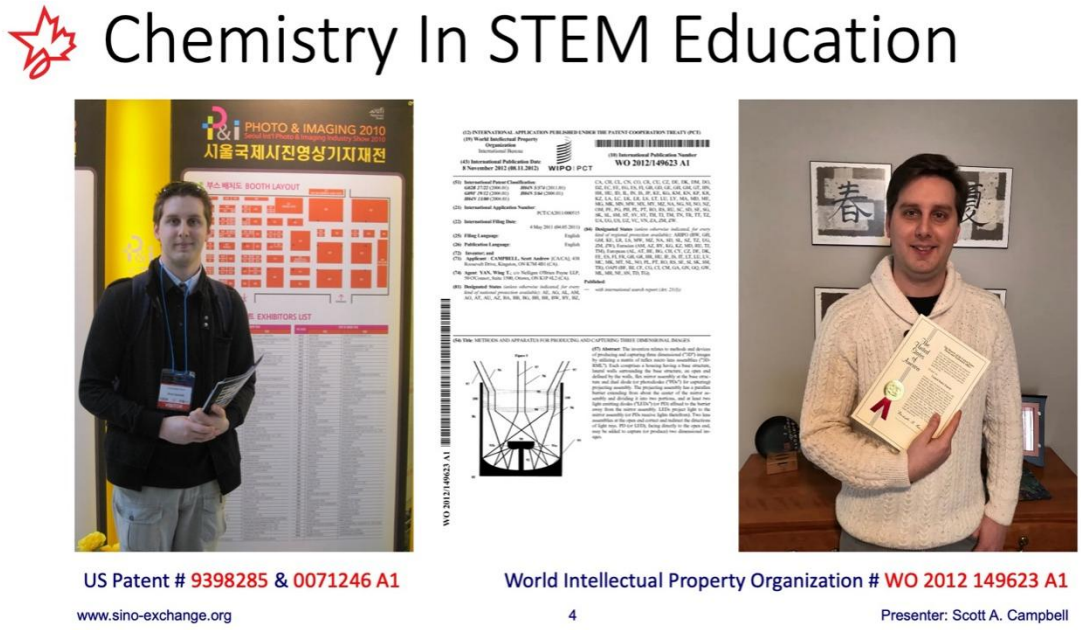
其次，我想谈谈什么是 STEM，因为围绕 STEM 教育的真实本质，总是有很多困惑。

接下来，我想给你一些真实世界中使用的化学例子，你可以用来设计真正的化学实验室。这些示例包括：

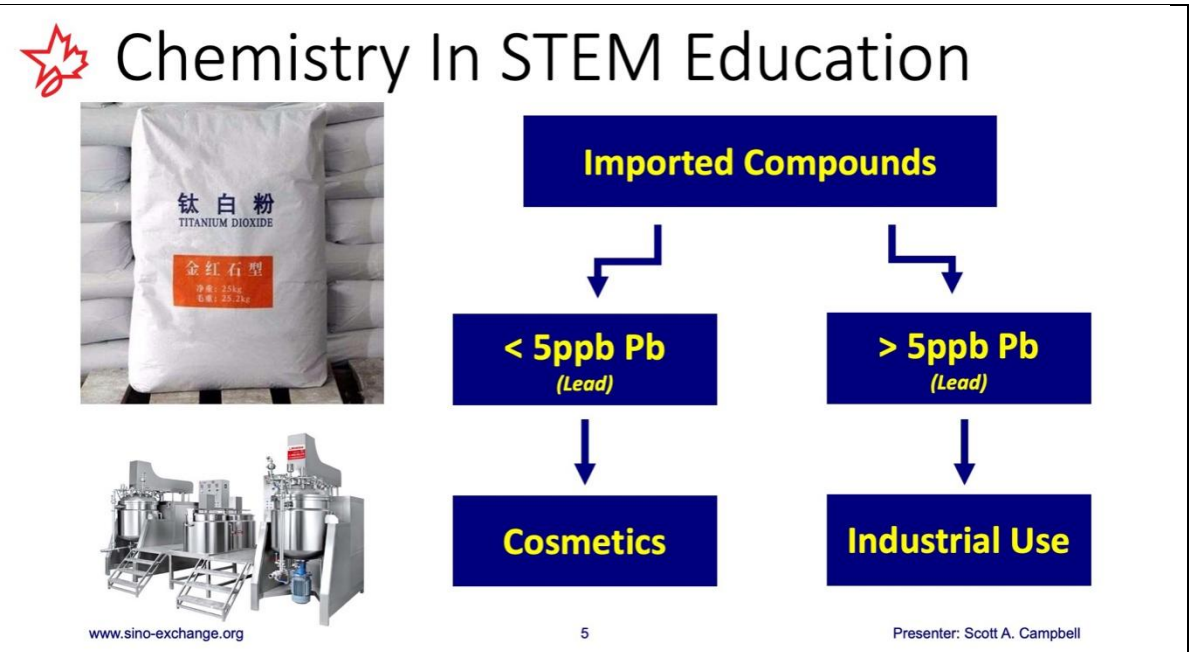
- 如何使用与健康和安全实验室技术人员相同的方法进行水分析。
- 在摄影中使用化学，这是创建交叉循环课程的好方法，可以在包括艺术的同时创造严格的学术学习成果。
- 最后，我们如何从电子垃圾中回收黄金等贵金属。

Moreover, this chemistry lab would also lay the foundation for some excellent philosophical debates that range from the environmental, social, and economic impacts of our actions!	• 此外，这个化学实验室还将为一些优秀的哲学辩论奠定基础，这些辩论包括我们行为对环境、社会和经济的影响！

Let's start with Big Idea #1 Drawing On Experience! One of the best ways to design and build authentic projects and curricula is to draw on lessons that you have learnt from either personal or professional experiences. Therefore, I would like to share with you some examples of how my experiences from working in industry have provided me with some invaluable insights into how chemistry can be applied to everyday problems, and I am going to show you how we can use that knowledge to create authentic learning opportunities that uphold the ideology of STEM education.	让我们从“大创意 1”开始 汲取经验！ 设计和构建真实项目和课程的最佳方法之一是吸取你从个人或专业经验中学到的经验教训。因此，我想与大家分享一些例子，说明我在行业工作的经验如何为我提供了一些宝贵的见解，让我了解化学如何应用于日常问题，我将向大家展示我们如何利用这些知识创造真正的学习机会，维护 STEM 教育理念。

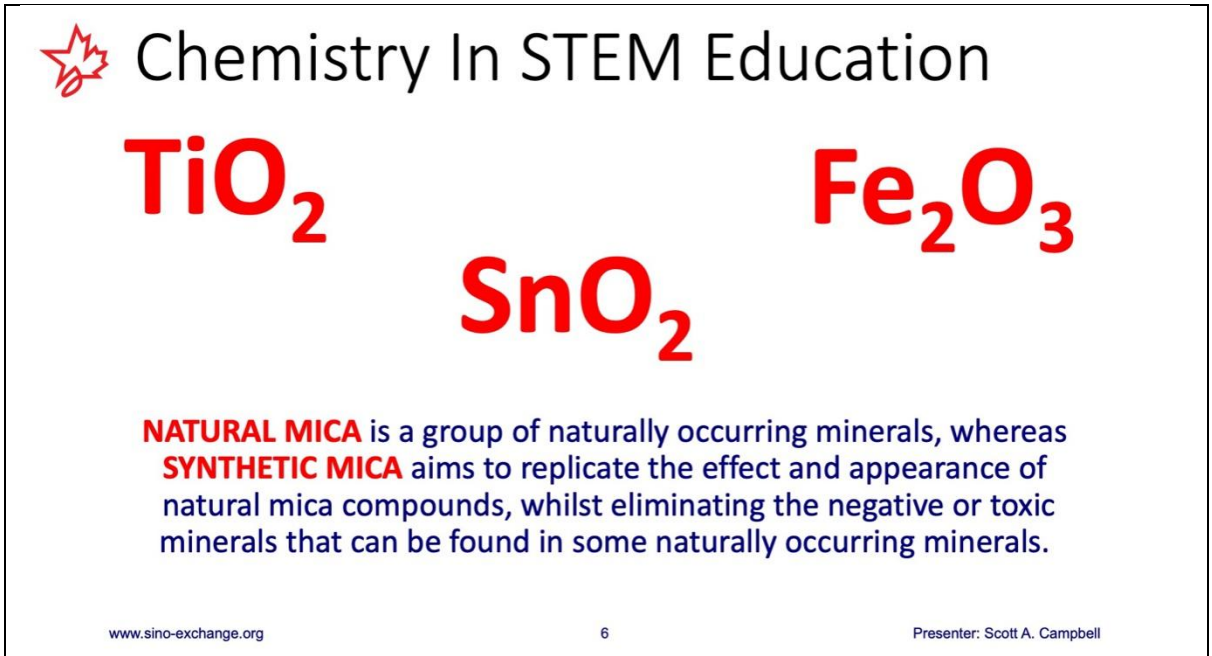


I started my first company in 2002, and by 2005 my company was officially operating with a federal TAX ID. Now my company was a small private consultancy that took on numerous projects over the years. Then, in 2010 my work in 3D imaging technologies took me to Korea, and by 2012 I had patented the world's first 3D Reflex Micro-Lens technology. Now if you are interested in this work, you can always review the patents should you like. I have the appropriate reference numbers up on the screen. However, unknown to me at the time, my work in 3D imaging would eventually take me into some interesting and unexpected markets.	我在 2002 年创办了我的第一家公司，到 2005 年，我的公司正式以联邦税号运营。现在，我的企业是一家小型私人咨询公司，多年来承接了许多项目。然后，在 2010 年，我在 3D 成像技术方面的工作将我带到了韩国，到 2012 年，我获得了世界上第一个 3D 反射微透镜技术的专利。 如果你对这项工作感兴趣，你可以随时查阅专利。我在屏幕上有相应的参考编号。然而，当时我并不知道，我在 3D 成像方面的工作最终会把我带入一些有趣和意想不到的市场。

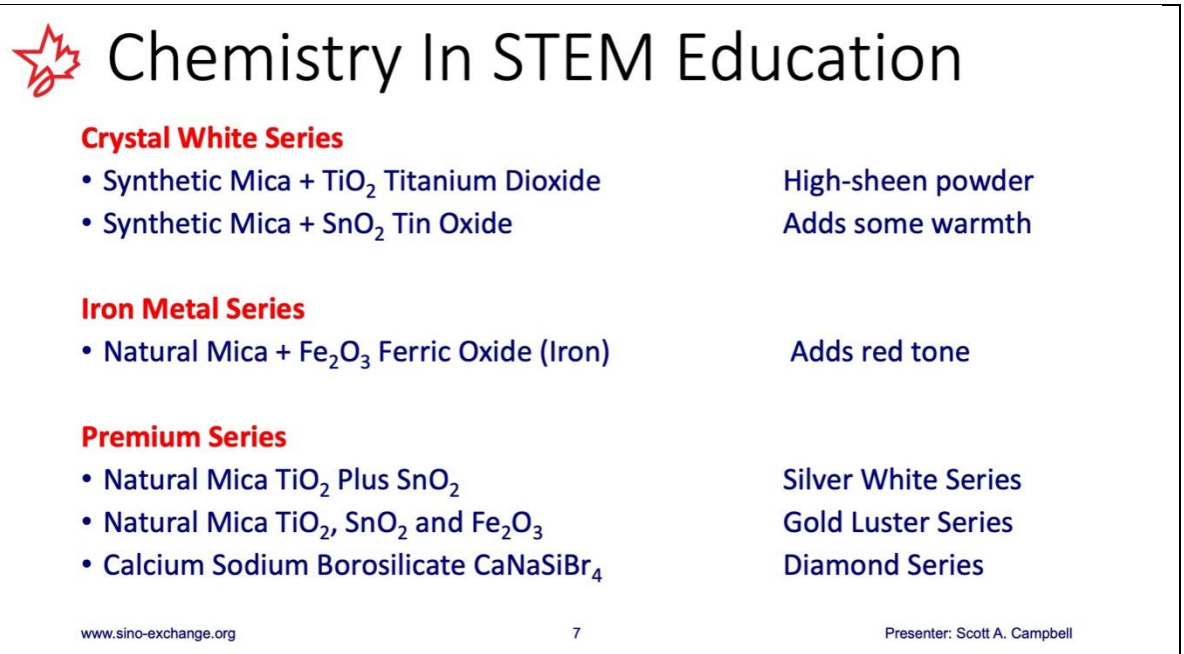


Although I would have even though it possible, my work in 3D imaging brought me into the realm of cosmetics. Yes… you heard me right. My work in 3D imaging brought me into the world of cosmetics! Although these two things seam completely different from one another, yet the company that I was consulting for had numerous business operations that involved a single supply chain. This supply chain started with importing raw materials, mostly from China, but also from America, Japan, and Germany. Many of the materials that were being imported included compounds such as: Titanium Dioxide, Tin Oxide, Ferric Oxide which were then further refined and resold, but the first thing that we always did was to test the quality of the raw materials. If the raw materials did not contain lead, then the raw materials could be used in the production of cosmetic. However, if the lead content exceeded a certain threshold, then the materials would be diverted to industrial applications. These applications included automatic paints and the development of electronics. Therefore, these raw materials might be used to create cosmetic or electronic products, and that was how my	尽管我曾想过这是可能的，我在 3D 成像方面的工作让我进入了化妆品领域。是的…你没听错。我在 3D 成像方面的工作让我进入了化妆品的世界！虽然这两件事看起来完全不同，但我所咨询的公司有许多业务运营，涉及到单一的供应链。 这条供应链从进口原材料开始，主要是从中国进口，但也从美国、日本和德国进口。许多进口的材料包括二氧化钛、氧化锡、氧化铁等化合物，这些化合物随后被进一步提炼和转售。但我们做的第一件事总是测试原材料的质量。如果原料不含铅，那么该原料可以用于化妆品的生产。然而，如果铅含量超过一定的阈值，那么这些材料将被转移到工业应用中。这些应用包括自动油漆和电子产品的开发。因此，这些原材料可能被用来制造化妆品或电子产品，这就是我在 3D 成像方面的工作如何将我带入化妆品世界。

work in 3D imaging brought me into the world of cosmetics.	



Now this aspect of my work gave me an amazing opportunity to learn something that was completely new to me, and I can now use these experiences when designing projects that apply chemistry in authentic ways to solve authentic real-world problems. Now I can't go through everything that we did but I do want to focus on a few key compounds to illustrate how real-life experiences can be invaluable to developing authentic STEM lessons. However, the three most important compounds that we used were: Titanium Dioxide, Tin Oxide, Ferric Oxide and Mica.	现在，我工作的这一方面给了我一个很好的机会去学习一些对我来说完全陌生的东西，我现在可以利用这些经验来设计项目，用真实的方式应用化学来解决真实的现实问题。现在我不能一一介绍我们所做的一切，但我想把重点放在几个关键的化合物上，以说明现实生活中的经历对开发真正的 STEM 课程是多么宝贵。然而，我们使用的三个最重要的化合物是：二氧化钛、氧化锡、氧化铁和云母。



Using these compounds, we created different compositions that were used by a wide variety of cosmetic and industrial applications. Although we had hundreds of combinations, here is a brief overview of some of the most important ones.

Our Crystal White Series included a high-sheen pigment that utilized Titanium Dioxide, and a secondary formulation which used Tin Oxide to create a pigment that had a slightly warmer colour tone.

Next, the most popular pigment from our Iron Metal Series used **Aluminum Potassium Silicate ($AlKO_6Si_2$)**, which is also known as natural mica. The natural mica was then mixed with **ferric oxide** to produce a soft lustrous compound that had reddish tone to it. Due to the unique nature of this composition, the pigment was used extensively in the production of cosmetic products such as blush.

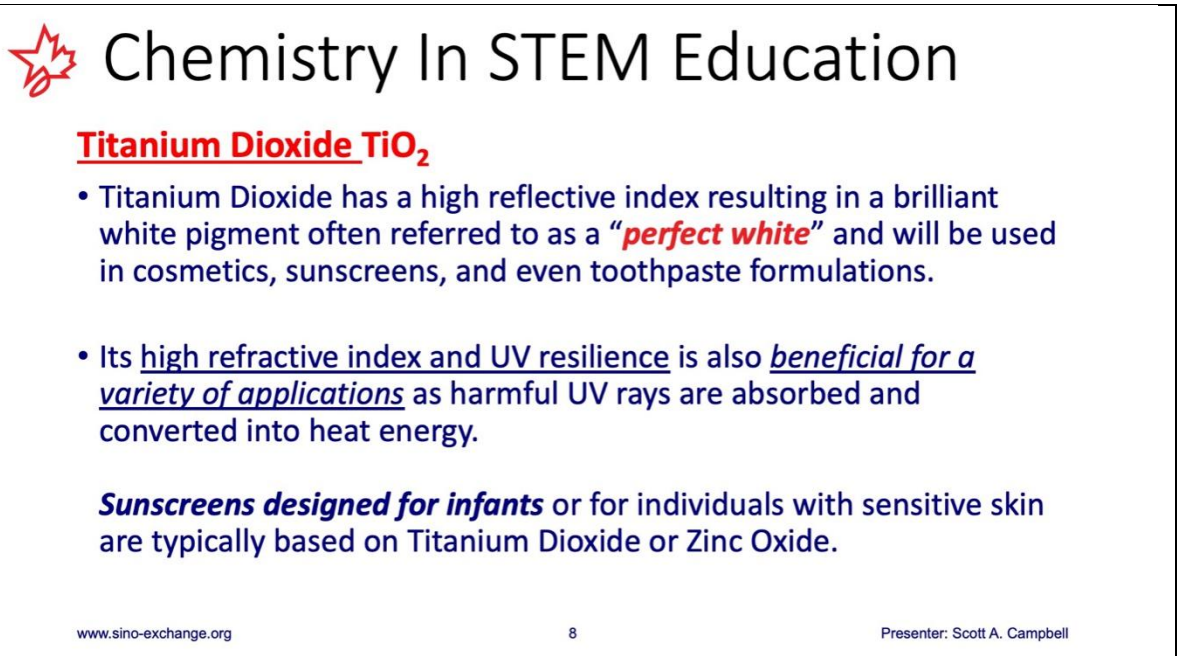
And finally, our premium series used natural mica in combination with other compounds that we have already discussed.

使用这些化合物，我们创造了不同的组合物，用于各种化妆品和工业应用。虽然我们有数百种组合，但这里简要概述了一些最重要的组合。

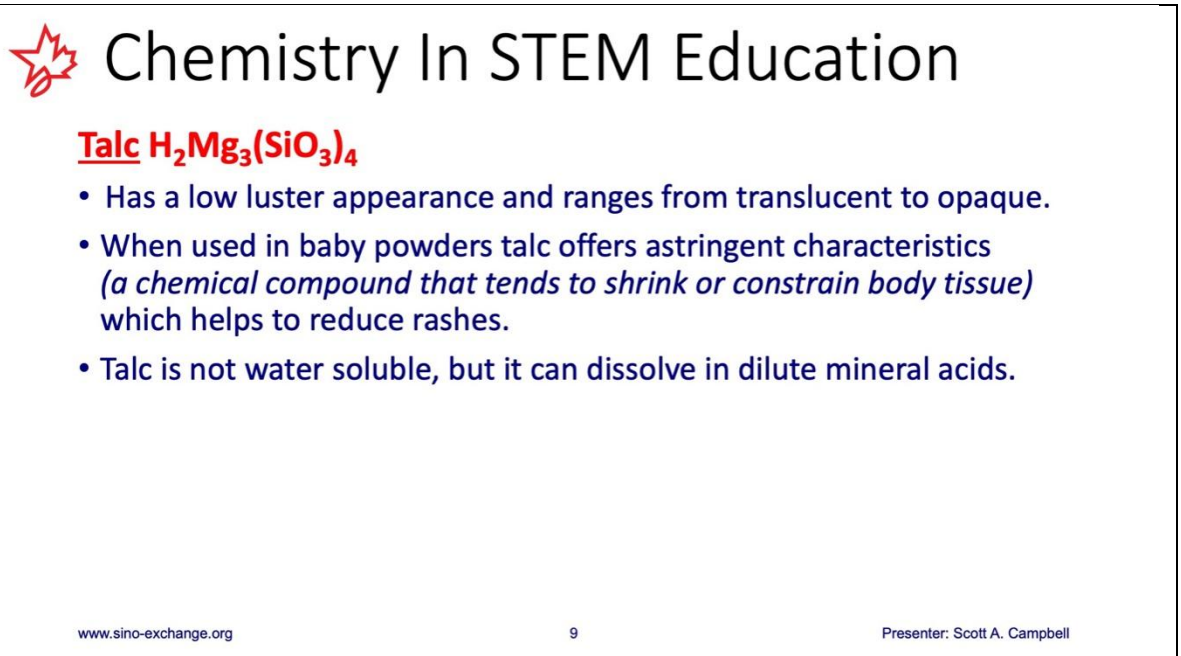
我们的水晶白系列包括使用二氧化钛的高光泽颜料，以及使用氧化锡的二次配方，以创建具有稍微温暖色调的颜料。

接下来，我们的铁金属系列中最受欢迎的颜料使用了硅酸铝钾（AlKO6Si2），也被称为天然云母。然后将天然云母与氧化铁混合，产生一种柔软、有光泽、略带红色的化合物。由于这种成分的独特性质，这种颜料被广泛用于生产化妆品，如腮红。

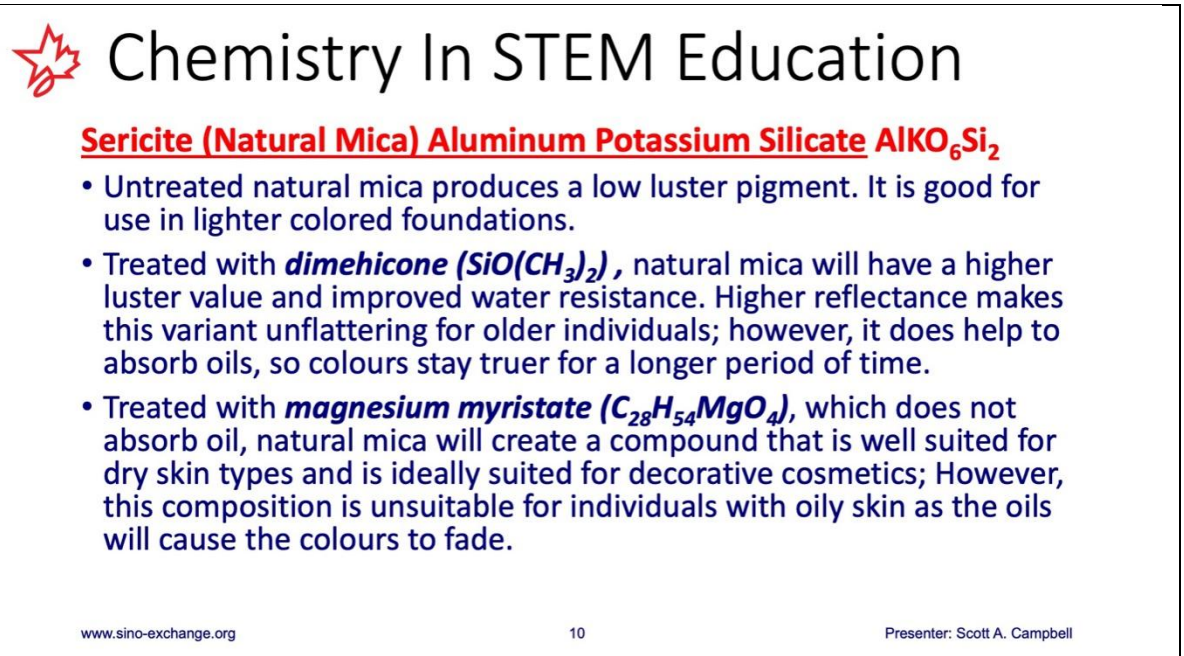
最后，我们的高级系列使用天然云母和我们已经讨论过的其他化合物的组合。



So, as you might have notice from the previous slide, **titanium dioxide** was a key component in the creation of many of the most popular product offerings. Now **titanium dioxide** has a high reflective index… and this results in a brilliant white pigment that is often referred to as a "*perfect white*". Some of the applications of **titanium dioxide** include cosmetics, sunscreen, and even toothpaste. Moreover, most sunscreens that are designed for infants or for individuals with sensitive skin are usually based on a **titanium dioxide** formulation due to its high refractive index and UV resilience.	所以，正如您在之前的幻灯片中可能已经注意到的，二氧化钛是创造许多最受欢迎的产品的关键成分。 二氧化钛有很高的反射指数，这就产生了一种明亮的白色颜料，通常被称为"完美白色"。二氧化钛的一些应用包括化妆品、防晒霜，甚至牙膏。此外，大多数为婴儿或敏感肌设计的防晒霜通常基于二氧化钛配方，因为它具有高折射率和抗紫外线能力。



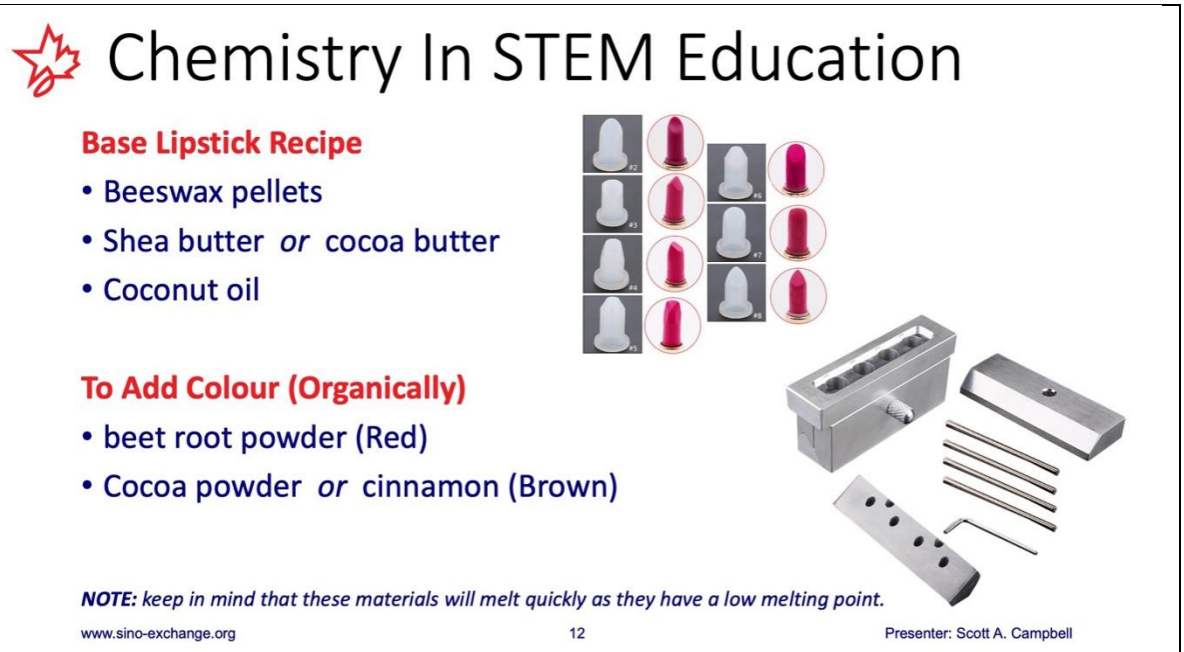
The next compound I walk to talk about is ***talc***, which is more commonly referred to as "***baby powder***". Talc has a low luster appearance that ranges from translucent to opaque. On its own ***talc*** is greasy to the touch and has a whitish grey colour. It is often used in cosmetics and baby powders as it has ***astringent*** characteristics which helps to reduce rashes. However, ***talc*** can be a bit tricky to work with as it is not water soluble; however, it can be dissolved in dilute mineral acids.	我要讲的下一种化合物是滑石粉，它通常被称为"婴儿爽身粉"。滑石粉具有从半透明到不透明的低光泽外观。滑石粉本身摸起来很油腻，呈白灰色。它经常被用于化妆品和婴儿爽身粉中，因为它具有收敛的特性，有助于减少皮疹。然而，滑石粉在运用中可能有点棘手，因为它不是水溶性的；但，它可以溶解在稀释的无机酸中。



And finally, I would also like to talk about **sericite** which is also known as **natural mica**. While there are many different types of **natural mica** compounds that are available on the market, we used **Aluminum Potassium Silicate ($AlKO_6Si_2$)**	最后，我还想谈谈绢云母，它也被称为天然云母。虽然市场上有许多不同类型的天然云母化合物，但我们使用了硅酸铝钾（AlKO6Si2）
Untreated, natural mica produces a low luster pigment which does not absorb oils; therefore, colours may fade if an individual's skin is very oily. It's good for use in lighter colored foundations and can be used in concentrations as high as 100%. When treated with **dimehicone, (a non-toxic silicone-based polymer) natural mica** will have a higher luster value and improved water resistance. However, higher reflectance values means that lines will become more noticeable due to higher contrast values. As a result, this formulation is often very unflattering for older individuals; however, this formulation does help to absorb oils, so colours stay truer for a longer.	未经处理的天然云母会产生一种不吸收油脂的低光泽颜料；因此，如果一个人的皮肤非常油腻，颜色可能会褪色。它适用于颜色较浅的粉底，可使用浓度高达 100%。当用二甲基硅酮（一种无毒的硅基聚合物）处理后，天然云母将具有更高的光泽值和更好的耐水性。然而，较高的反射率值意味着由于较高的对比度值，线条将变得更加明显。因此，这种表述对老年人来说通常是非常不讨人喜欢的；然而，这种配方确实有助于吸收油脂，所以颜色保持得更久。
When treated with **magnesium myristate** (which doesn't absorb oil), the formulation will create a compound that is well suited for dry skin types as well as darker	当用肉豆蔻酸镁（不吸收油脂）处理时，该配方将产生一种非常适合干性皮肤和深色粉底的化合物。因为它增加了对皮肤的附着力，提高了耐磨性，并且

foundation colours. Because of it increased adhesion to skin, improved wear resistance, and its high binding power… this formulation is ideal for decorative cosmetics. However, this composition is unsuitable for individuals with oily skin. Now without revealing to many trade secrets, we would also apply a silicon coating to many of the product that were destined for use in cosmetics. This silicon coating would add hydrophobic characteristics to the various compounds. This silicon coating would be applied as a liquid mist as the pigment were being mixed and this process happened slowly to insure evenness and constancy. Finally, a small amount of heat was applied during the mixing process to evaporate the solvent which helped to ensure that the mixing process didn't produce clumps. The whole process would take about 30 minutes per batch and used an alcohol-based solvent.	具有很高的粘合力……这种配方是装饰化妆品的理想选择。然而，这种组合物不适合油性皮肤的人。 在不泄露商业秘密的情况下，我们还会在许多用于化妆品的产品上涂上一层硅涂层。这种硅涂层将增加各种化合物的疏水特性。在颜料混合的过程中，这种硅涂层会像液体雾一样被涂上，这个过程进行得很慢，以确保均匀性和恒定性。最后，在混合过程中施加少量热量来蒸发溶剂，这有助于确保混合过程不会产生团块。整个过程每批大约需要 30 分钟，并且使用的是酒精溶剂。

Now why did I tell you all about my unexpected foray into the world of cosmetics? Well making lipsticks in class can be a fun way to get student to learn how to use lab equipment. Moreover, it also applies basic chemistry skills to create a real-world product that the students can actually use, but more importantly, it's also great way **to inspire more young women** to get interested in STEM education.	我为什么要告诉你我对化妆品世界的意外探索呢？ 在课堂上做口红会是一种让学生学习如何使用实验室设备的有趣的方式。此外，它还应用基本的化学技能来创造一个学生可以实际使用的现实世界的产品，但更重要的是，这也是激励更多年轻女性对 STEM 教育感兴趣的好方法。



While your students are not going to be able to mass-produce cosmetic products using the compounds that I discussed earlier. Specifically, as they will not be able to conduct the necessary quality control requirements to ensure that the final product is safe for human use it's still possible to simulate the big ideas by creating organic approximations that would accurately simulate a real product.

While exact chemistry will not be needed in this example, students would still need to practice various lab skills which would make this kind of activity a great point-of-entry project for middle-school students. So let me explain how you could make lipstick quickly and easily with your students. Everything that you will need is currently listed or shown here.

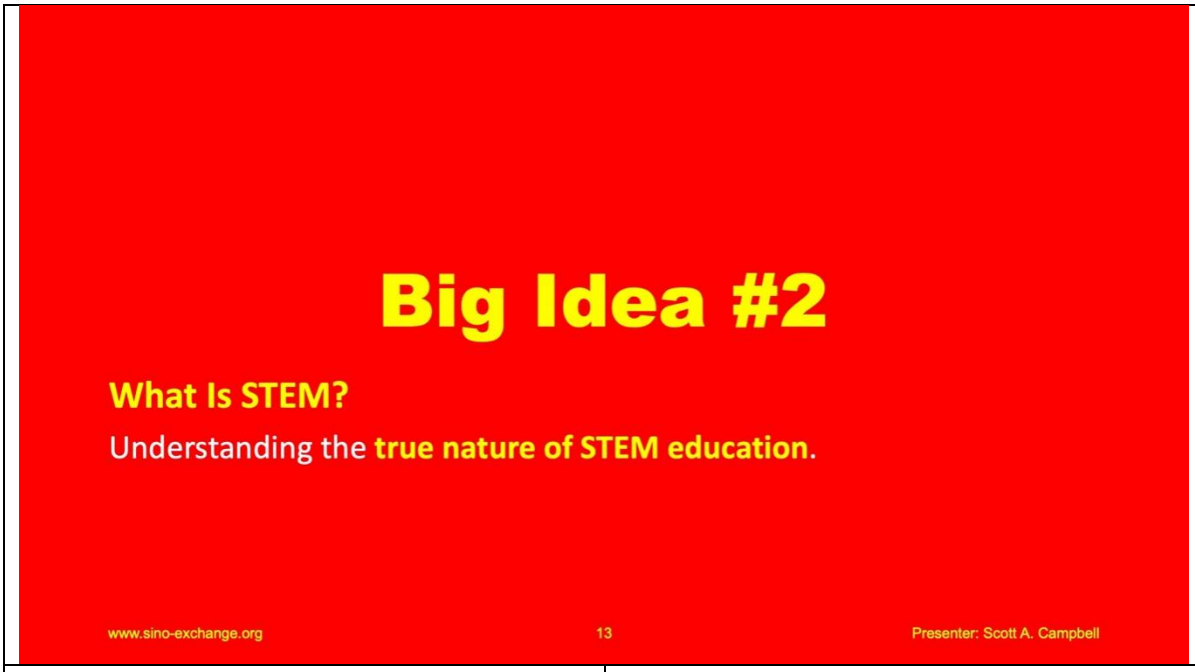
- Now the first thing that you will need to do is melt **beeswax**, **shea butter** and some **coconut oil** in a glass beaker, but make sure you do not use a direct heat source. Therefore, it is best to immerse the beaker it hot water (hot, not boiling water).
- Next once melted and mixed, remove the mixture from the heat source and add any desired scents or color

而你们的学生将无法使用我之前讨论过的化合物批量生产化妆品。具体来说，由于他们将无法执行必要的质量控制要求，以确保最终产品对人类使用是安全的，因此仍然可以通过创建能够准确模拟真实产品的相似体来模拟大创意。

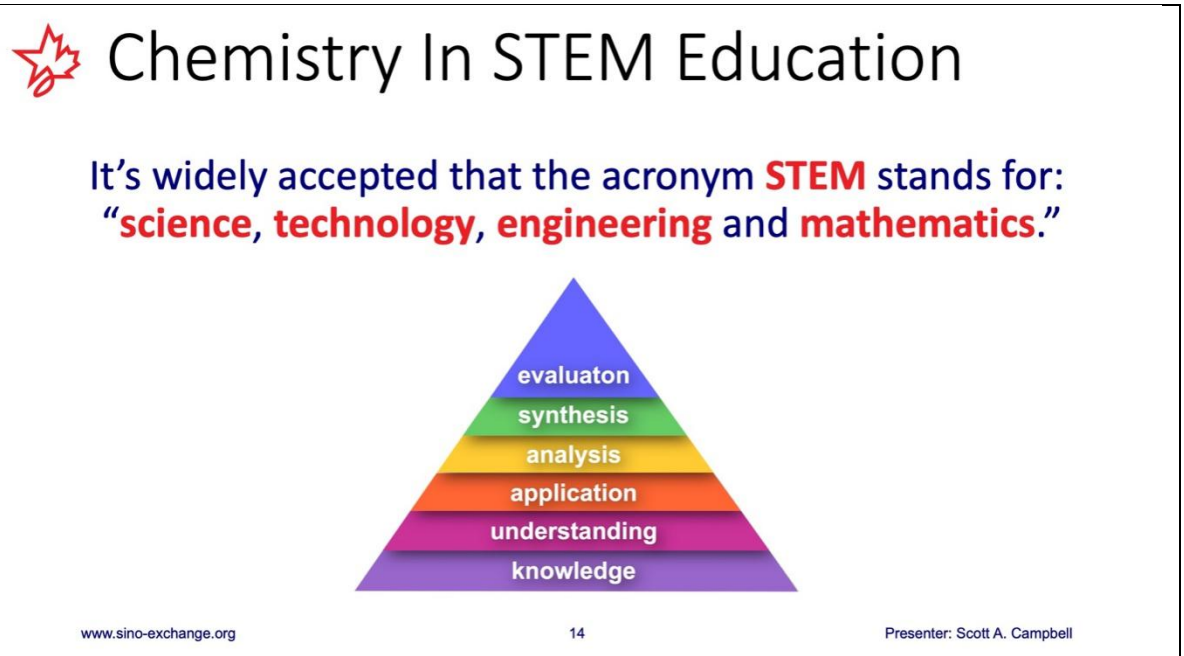
虽然在这个例子中不需要精确的化学，但学生们仍然需要练习各种实验室技能，这将使这种活动成为中学生的一个很好的入门项目。所以，让我来解释一下你是如何和你的学生一起快速轻松地制作口红的。您需要的一切都在这里列出或显示。

- 现在你需要做的第一件事是在一个玻璃烧杯里融化蜂蜡、乳木果油和一些椰子油，但要确保不要使用直接热源。因此，最好将烧杯浸泡在热水中（热水，而不是开水）。
- 接下来，一旦融化并混合，将混合物从热源中取出，并添加任何所需的气味或颜色添加剂。

additives. • Then, once all the ingredients are mixed, pour the mixture into the lip chap container. Be sure not to fill the mold all the way to the top as the lipstick will expand slightly as it cools. While you can use in-expensive silicon molds, you may also consider using professional grade stainless steel molds, just like what we would use to create pre-production testers in the lab. Either way, with minimal pre-requisites you and your students can apply chemistry in an authentic way to create a real-world product in about one hour, and this kind of activity should really help to get some of the young women in your class just a little bit more interested in the sciences.	• 然后，当所有成分混合后，将混合物倒入唇裂容器中。切记不要把口红全部填满模具，因为口红冷却后会略微膨胀。 虽然你可以使用昂贵的硅模具，但你也可以考虑使用专业级不锈钢模具，就像我们在实验室中用于创建预生产测试一样。不管怎样，在最小的必备条件下，你和你的学生们可以用一种真实的方式应用化学，在大约一个小时内做出一个真实的产品。这种活动应该真的有助于让你班上的一些年轻女性对科学更感兴趣。



That brings us to Big Idea #2, which is improve our understanding of the **true nature of STEM education**. So, you're probably thinking, what other experiments can I do in my classes that will apply chemistry into a variety of real-world contexts? And this is what STEM is all about. Using Science, Technology, Engineering and Math skills in an authentic context through a variety of real-world lessons, but there is so much confusion around STEM education now a days! So, it is important that we take a moment to develop a common understanding of STEM education.	这就引出了第二个大想法，即提高我们对 STEM 教育本质的理解。 所以，你可能在想，我在课堂上还能做什么其他实验，将化学应用到各种现实环境中去？这就是 STEM 的意义所在。通过各种现实世界的课程，在真实的背景下使用科学、技术、工程和数学技能，但现在 STEM 教育有太多的困惑！因此，我们有必要花点时间对 STEM 教育形成共识。



It's widely accepted that **STEM** stands for: "**science**, **technology**, **engineering** and **mathematics**." It seems that everybody knows what STEM is, but there's still a lot of confusion and uncertainty surrounding STEM and all its derivatives. So let me delve into this a bit more. Now I think most people are aware of Blooms taxonomy, but for those of you who don't – Blooms taxonomy is a classification of the different levels of thinking or cognition. Where knowledge is at the bottom, and as we develop our understandings, we can start applying what we know and eventually start synthesising and evaluating the results of our own thought process -- and I think that this is an important thing for us to stop and think about. **Everybody seems to have knowledge of what STEM is, but very few people understand the true nature of STEM education**, and we as educators we know that there is a **big difference between knowledge and understanding**. Now because of the confusion surrounding STEM education there has been numerous	人们普遍认为 STEM 代表"科学、技术、工程和数学" 似乎每个人都知道什么是 STEM，但围绕 STEM 及其衍生产品仍有很多困惑和不确定性。所以让我再深入研究一下。 现在我想大多数人都知道布鲁姆斯的分类法，但对于那些不知道的人来说——布鲁姆斯分类是对不同层次的思维或认知水平的分类。在知识处于底层的地方，当我们发展我们的理解时，我们可以开始应用我们所知道的，并最终开始综合和评估我们自己思考过程的结果——我认为这对我们来说是一件重要的事情，需要停下来思考。似乎每个人都知道什么是 STEM，但很少有人理解 STEM 教育的真正本质，作为教育工作者，我们知道知识和理解之间有很大的区别。 现在，由于围绕 STEM 教育的混乱，多年来对该框架提出了许多批评…

criticisms made of the framework over the years…	

Chemistry In STEM Education

There is a lot of confusion surrounding STEM education as there no common perception or language of what STEM is anymore due to the development of numerous STEM derivatives such as:

- STEM
- STEAM
- STEMS
- STEMMA
- eSTEM + eSTEAM
- STREAM (adds "reading" or "research" and "arts")
- STEMM founded by Dr. Steve Meyer, & Rev. Jon Gerdts

"countries with high English proficiency are more innovative as they have access to a wider breadth of current research material from the global community" (Tran, 2015).

Tran, M., 2015. *Countries with High English Proficiency Are More Innovative.* [Online]
Available at: https://hbr.org/2015/11/countries-with-high-english-proficiency-are-more-innovative Page 1 of 6 [Accessed 5 2020].

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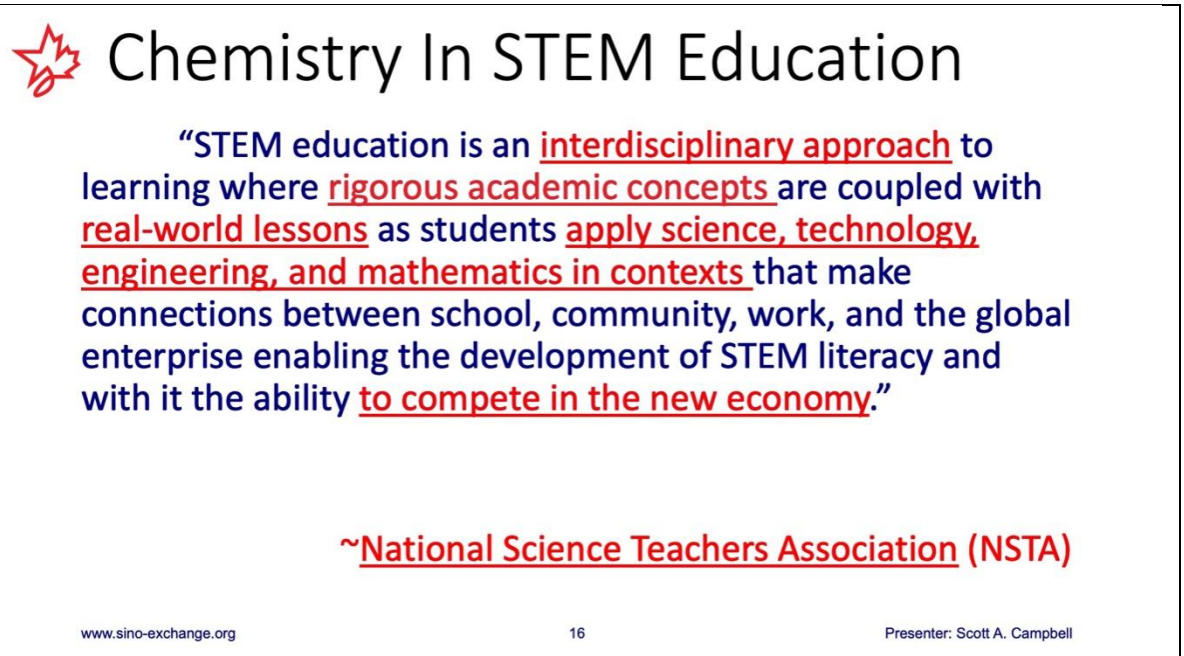
While these criticisms are valid. They only identified a problem **without understanding what caused the problem in the first place**, and this criticism resulted in a numberer of STEM derivatives which have only created more confusion for educators and administrators alike! So, let's look at some of these acronyms.

- We have STEM.
- And we also have STEAM which adds creativity through the arts.
- But we also have STEMS which recognizes the importance Social Sciences by adding the S at the end of the acronym.
- STEMMA adds Managerial Arts and was first proposed by Harvard University.
- Next, we have eSTEAM which recognizes the importance of developing English literacy development, and this idea of including an ESL curriculum into the STEM framework is important for none-English speaking countries so that students can access a wider range of research materials which will help them become more innovative.
- Which leads us to another derivate know as STREAM with adds reading or research.

虽然这些批评是正确的。他们只发现了一个问题，而不了解导致问题的原因，这种批评导致了许多 STEM 衍生品，这只会给教育工作者和管理者带来更多的困惑！那么，让我们来看看其中的一些缩写词。

- 我们有 STEM。
- 我们还有 STEAM，它通过艺术增加了创造力。
- 但我们也有 STEMS，它通过在首字母缩写的末尾添加 S 来认识到社会科学的重要性。
- STEMMA 增加了管理艺术，最早由哈佛大学提出。
- 接下来，我们有 eSTEAM，它认识到发展英语读写能力的重要性，将 ESL 课程纳入 STEM 框架的想法对非英语国家来说很重要，这样学生就可以获得更广泛的研究材料，这将有助于他们变得更具创新性。
- 这就引出了另一个衍生词 STREAM，即附加阅读或研究的 STREAM。

• And finally, we have STEMM with a double M which was created by Dr. Steve Meyer and Revant Jon Gerdts who add the values of Christin Missionary to the the mandate of STEM education. While slightly religious in nature, this idea does tie in with the recommendations that the World Economic Form had made about considering the social aspects of what we do, but it does it from a religious standpoint. However, this idea also aligns with the Chinese interpretation of STEM, which they refer to as STEM + [sù zhì jiào yù], or moral education which addresses this need from a more secular standpoint.	• 最后，我们有一个带有双 M 的 STEMM，由 Steve Meyer 博士和 Revant Jon Gerdts 创建，他们将基督教传教士的价值观添加到 STEM 教育的任务中。虽然这个想法本质上有点宗教色彩，它是从宗教的角度出发的，但它确实与《世界经济形式》提出的关于考虑我们行为的社会方面的建议相吻合。 然而，这一想法也符合中国人对 STEM 的解释，他们称之为 STEM+[súzhìjiào yú]……或从更世俗的角度解决这一需求的道德教育。



So, this definition of STEM education upholds the original ideology that Judith Ramaley had for STEM when she introduced the concept back in 2001. Let's take a moment to read through this definition together…

"STEM education is an interdisciplinary approach to learning where rigorous academic concepts are coupled with real-world lessons as students apply science, technology, engineering, and mathematics in contexts that make connections between school, community, work, and the global enterprise enabling the development of STEM literacy and with it the ability to compete in the new economy."

WOW!

This definition is very verbose!
So, I am going to highlight a few key words here:

- interdisciplinary approach
- rigorous academic concepts
- real-world lessons
- apply science, technology, engineering, and mathematics in contexts
- to compete in the new economy

因此，STEM 教育的这一定义维护了朱迪斯·拉马利在 2001 年引入 STEM 概念时对 STEM 的原始意识形态。让我们花点时间一起通读这个定义…

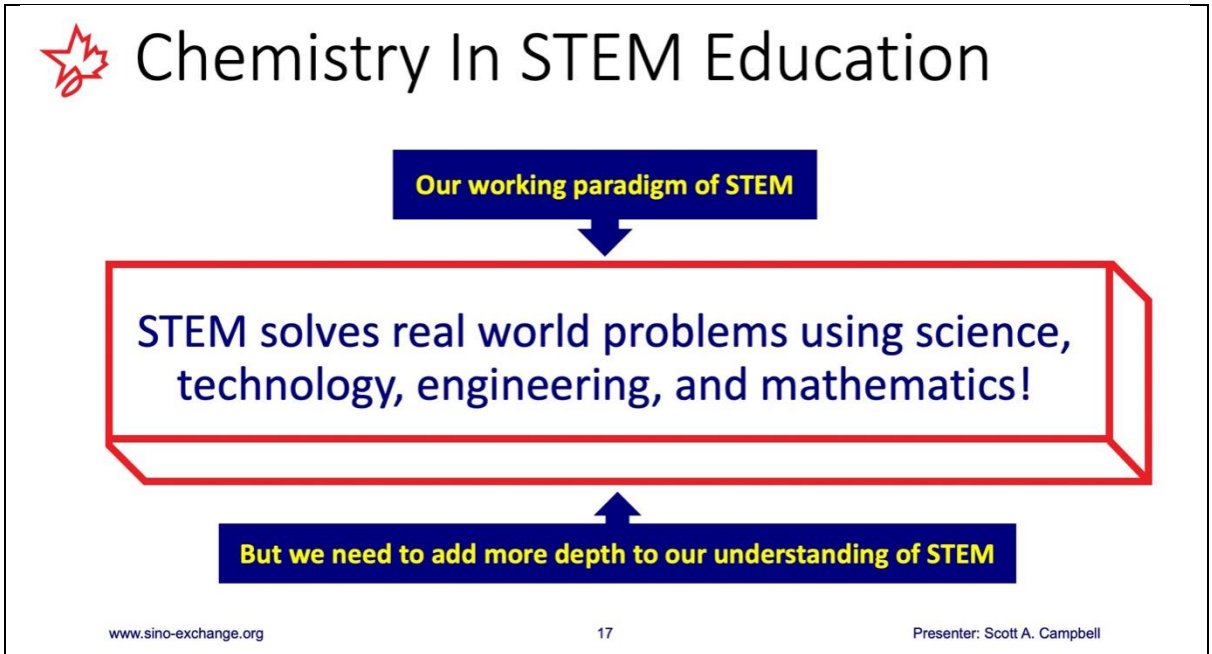
"STEM 教育是一种跨学科的学习方法，学生在学校、社区、工作和全球企业之间建立联系的背景下应用科学、技术、工程和数学将严谨的学术概念与现实世界的课程相结合，从而提高 STEM 素养，并以此提高在新经济中竞争的能力。"

哇!

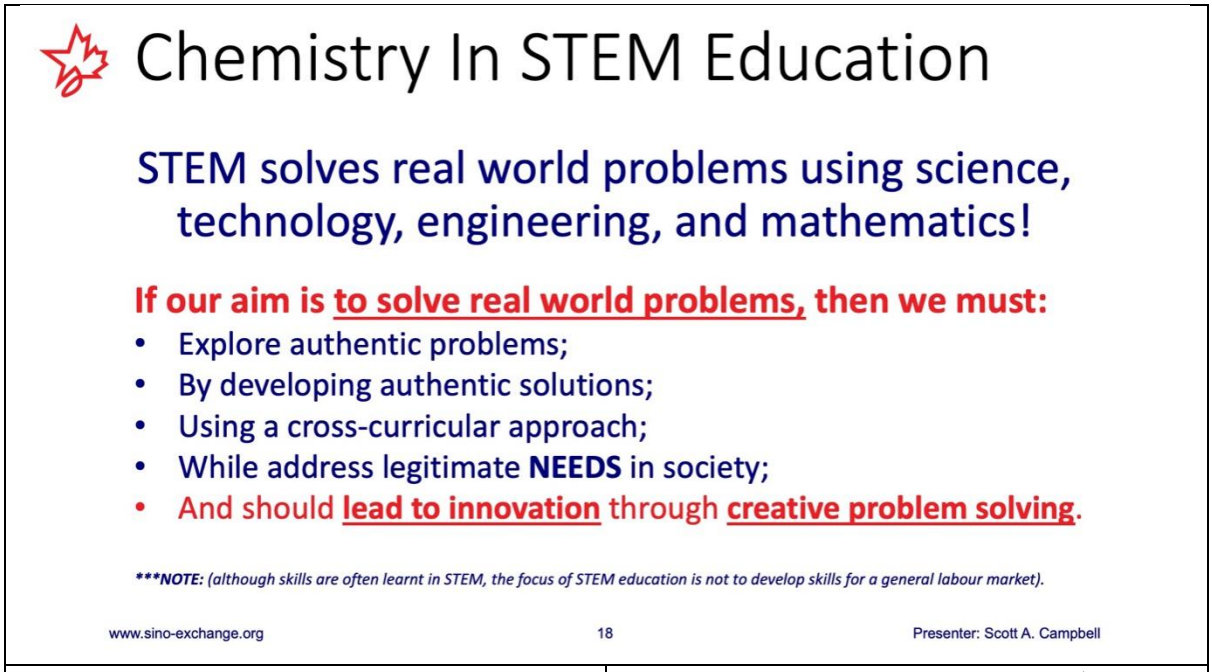
这个定义非常冗长!
因此，我将在这里强调几个关键词：

- 跨学科方法
- 严谨的学术理念
- 现实世界的经验教训
- 将科学、技术、工程和数学应用于环境中
- 在新经济中竞争

As we can see by this last statement, STEM is linked to economic goals. To help students compete in the new global economy! Therefore, we can't really forget about this connection because it's really the main driving force for STEM education at the government level. But let's try simplifying this definition before moving on.	正如我们从最后一句话中看到的，STEM 与经济目标有关。帮助学生在新的全球经济中竞争！因此，我们不能真的忘记这种联系，因为它确实是政府层面 STEM 教育的主要驱动力。但在继续之前，让我们试着简化这个定义。



STEM solves real world problems using science, technology, engineering, and mathematics! This is the simplest definition that I can make to define STEM education. However, this perception of STEM education, which I represented by a red box is incredibly limited. Therefore, we need to add more depth to our working paradigm. So, lets expand on this idea and add a bit more depth to our understanding of STEM education.	STEM 利用科学、技术、工程和数学解决现实世界中的问题! 这是我能为 STEM 教育下的最简单定义。然而，我用红框表示的这种对 STEM 教育的看法是非常有限的。因此，我们需要为我们的工作模式增加更多的深度。因此，让我们扩展一下这个想法，让我们对 STEM 教育的理解更深入一些。



So, if our aim is to solve real world problems then:

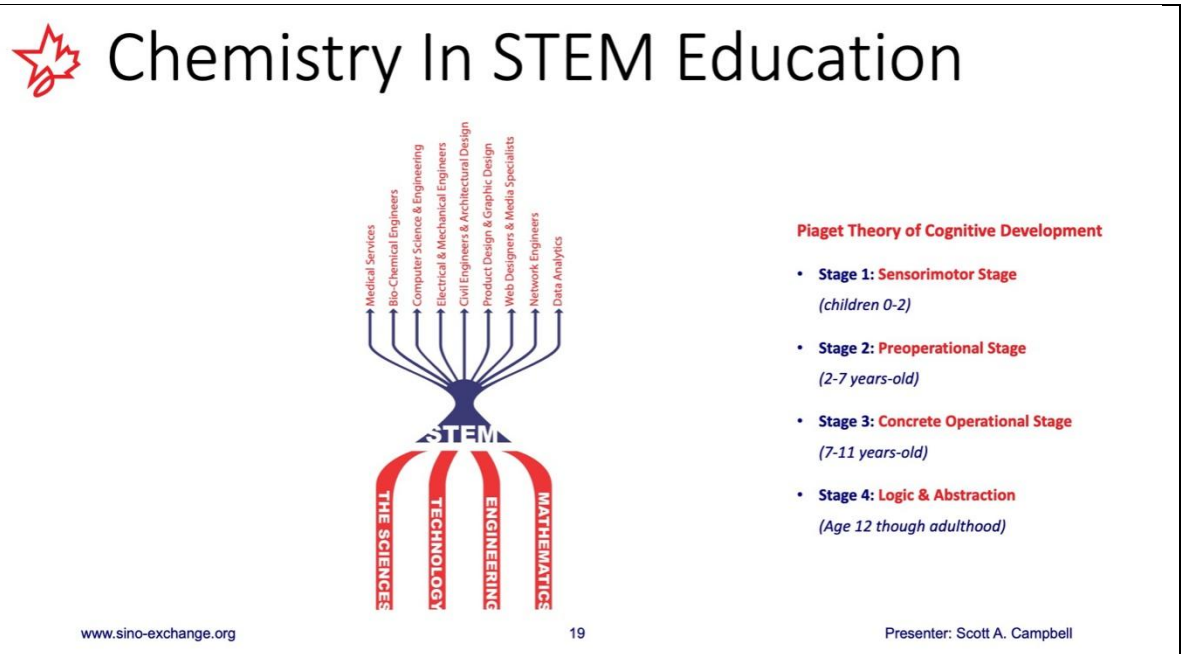
- Then the problems that we explore should be authentic.
- By extension, the solutions to that problem should also be authentic.
- And finally, the approach should also be cross-curricular in nature.
- But professionals in the fields of STEM are also addressing real world needs in our society. Therefore, these industry professionals are leading innovation through creative problem solving.

We now have a definition that is much simpler to understand, and it still upholds the ideology of the original definition that we had previously looked at. However, there is still one last point that I should emphasize! Although students will often learn numerous hands-on skills in a STEM class, the focus of STEM education is not to develop job skills for a general labour market.

因此，如果我们的目标是解决现实世界中的问题，那么：

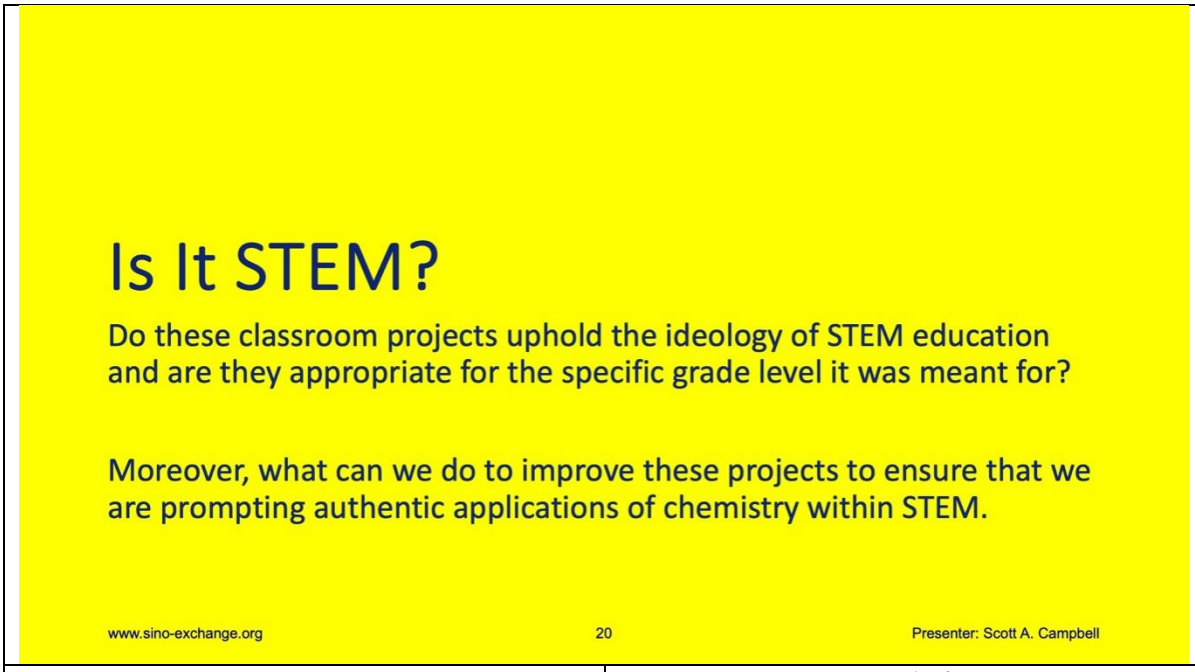
- 那么我们探索的问题应该是真实的。
- 从广义上讲，这个问题的解决方案也应该是真实的。
- 最后，这种方法在本质上也应该是跨课程的。
- 但 STEM 领域的专业人士也在满足我们社会的现实需求。因此，这些行业专业人士正在通过创造性的问题解决来引领创新。

我们现在有了一个更容易理解的定义，它仍然坚持我们以前看到的原始定义的意识形态。然而，还有最后一点我应该强调！尽管学生们通常会在 STEM 课堂上学习许多动手技能，但 STEM 教育的重点并不是为一般劳动力市场培养工作技能。

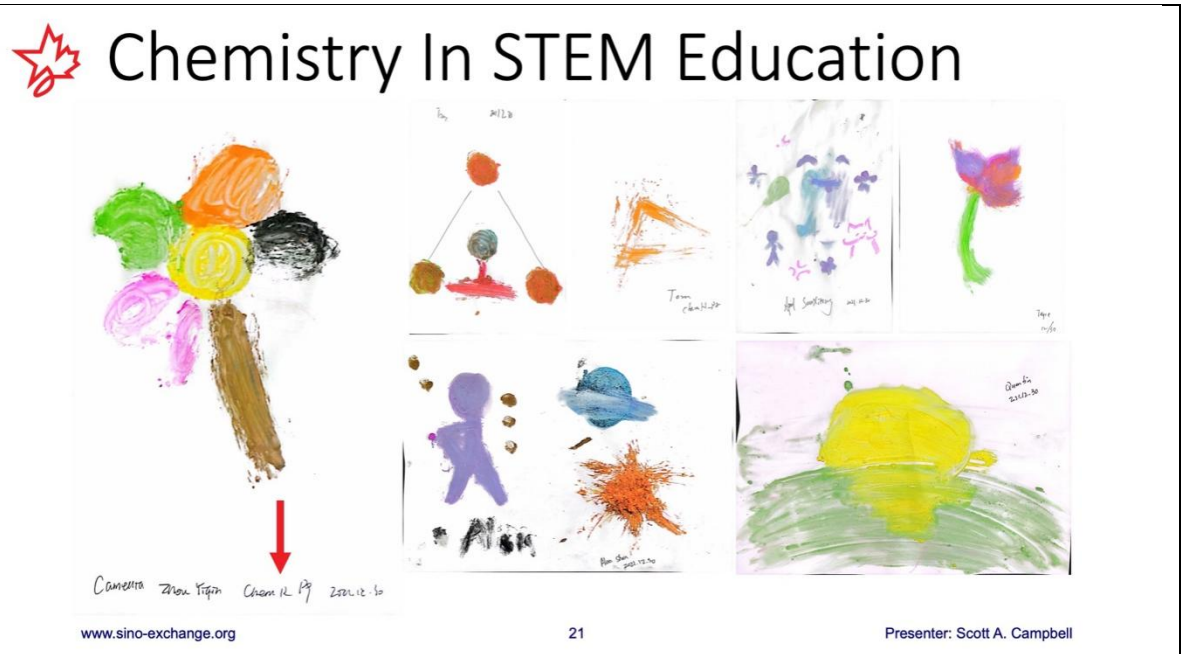


In conclusion, I would like to share this graphic with you to show you how all these different concepts are interconnected with one another. • From the various subjects that STEM is comprised of; • The critical industry sectors that STEM is related to; • The educational theory that intersects with STEM education; • And the various stages of cognitive development in children. As you can see the core subjects Science and Mathematics act as columns supporting everything, and these core subjects are supplemented by inter-disciplinary subject areas. Therefore, STEM acts as merging point for the core subjects as we apply rigorous academic concepts in real-world lessons that will help students prepare themselves for the new global economy. However, there are so many critical sectors that are represented by STEM. Therefore, after we see the merging of the core subjects, we also see STEM branch out into a wide range of specializations that all fall under the STEM umbrella. This creates an hourglass shape	最后，我想与大家分享这张图，向大家展示所有这些不同的概念是如何相互关联的。 • 从 STEM 所包含的各个科目来看； • STEM 相关的关键行业部门； • 与 STEM 教育交叉的教育理论； • 以及儿童认知发展的各个阶段。 正如你所看到的，科学和数学是支撑一切的支柱，这些核心学科由跨学科学科领域补充。因此，STEM 是核心学科的融合点，因为我们在现实世界的课程中应用了严格的学术概念，这将帮助学生为新的全球经济做好准备。然而，STEM 代表了许多关键部门。因此，在我们看到核心学科的融合之后，我们也看到 STEM 分支到了广泛的专业领域，这些专业都属于 STEM 的保护伞下。这就形成了一个沙漏形状，因为我们接受了多个科目，将它们放在一起，然后在以后的生活中专门从事某个特定的研究领域时再次扩展。 这让我想到了 Blooms Taxonym。正如你所看到的，我们总是从知识开始，当我们学习基础知识时，我们开始理解抽象

as we take multiple subjects, bring them all together, and then branch out again as we go on to specialize in a specific field of study later in life. And that brings me to **Blooms Taxonym**. As you can see, we always start with knowledge, and as we learn the basics, we start to understand abstract concepts. These concepts could include how to solve an equation, or how molecular bonds work and these are important concepts to understand if we are going to start applying these theories in a STEM program. Therefore, the core subjects really need to proceed STEM, because we cannot apply math and science before first understanding the basics. Then in STEM we can start applying what we have learnt in an authentic context to solve real-world problems before we can move on and analyze the results. And finally, later in life, industry professionals are required to synthesis seemingly unrelated concepts to solve complex problems in the real-world and of course, they will need to evaluate the effectiveness of those solutions as well! Next, we can look at where we are going to get the greatest impact from a STEM program of study. Since critical thinking, math, and science are critical skill sets that are crucial to STEM education, you will find that STEM will have the greatest impact when it is taught at middle and high-school levels. And this notion also corresponds well with what we know of **Piaget Theory of Cognitive Develop** which indicates that "**logic and abstraction**" only starts at age 12 and continues through adulthood.	概念。这些概念可能包括如何求解方程，或者分子键如何工作，如果我们要开始在 STEM 项目中应用这些理论，这些都是需要理解的重要概念。因此，核心科目确实需要继续 STEM，因为我们不能在先了解基础知识之前应用数学和科学。然后，在 STEM 中，我们可以开始在真实的环境中应用我们所学的知识来解决现实世界中的问题，然后再继续分析结果。最后，在以后的生活中，行业专业人员需要综合看似不相关的概念来解决现实世界中的复杂问题，当然，他们也需要评估这些解决方案的有效性！ 接下来，我们可以看看 STEM 研究项目将在哪里产生最大影响。由于批判性思维、数学和科学是对 STEM 教育至关重要的关键技能，你会发现 STEM 在中学和高中阶段的教学将产生最大的影响。这一概念也与我们所知的皮亚杰认知发展理论相吻合，皮亚杰认知发育理论表明，"逻辑和抽象"只从 12 岁开始，一直持续到成年。

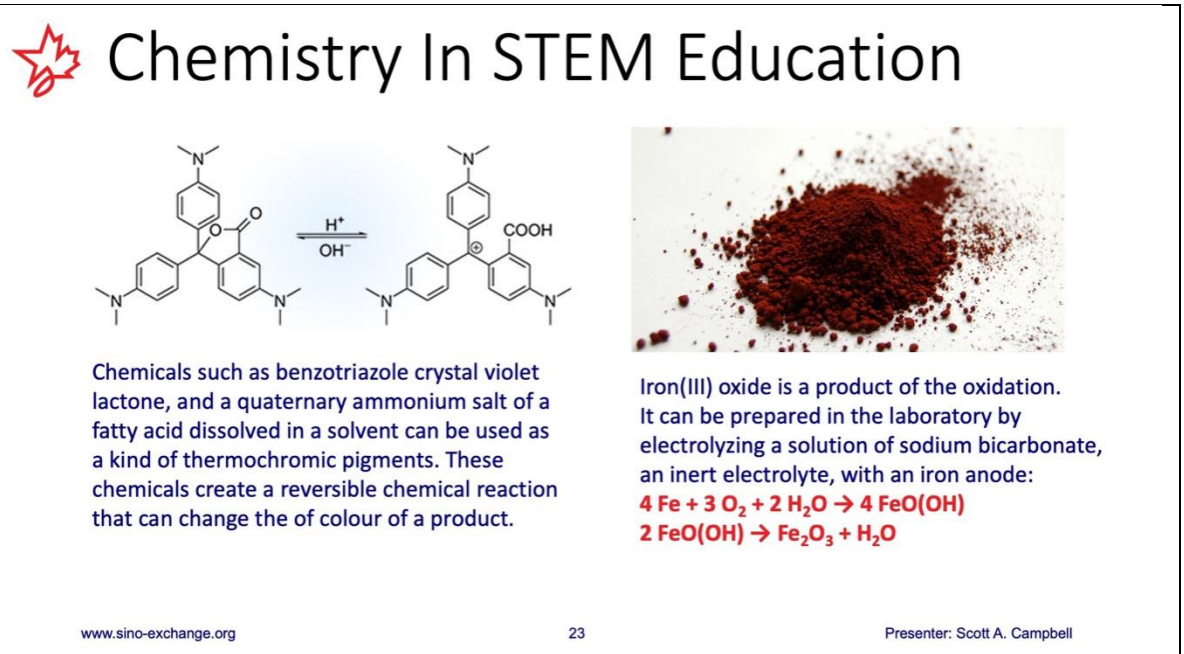


Now that we have some common understandings about STEM education, let's look at some classroom examples to determine if these classroom projects represent the true nature of STEM education, and what we can do to modify our lesson plans to ensure that we are achieving the desired learning outcomes.	既然我们对 STEM 教育有了一些共同的理解，那么让我们看看一些课堂例子，以确定这些课堂项目是否代表了 STEM 教育的真实性质，以及我们可以做些什么来修改我们的课程计划，以确保我们实现期望的学习结果。



Let's start with this STEM project. This was a project that was used to promote a school's STEM program. Now what grade level do you think this project was for? What about now? This was a grade 12 honors chemistry project where the students were learning about creating water resistant paints. Now you might be thinking, just as I am right now! That this activity does not appear to be appropriate for that grade level, but the school was proud of it because the students had used the school's lab spaces and had also been engaged in a hands-on learning activity.	让我们从这个 STEM 项目开始。这是一个用于促进学校 STEM 项目的项目。现在，你认为这个项目是为了哪个年级水平？ 现在呢？ 这是一个 12 年级的荣誉化学项目，学生们正在学习如何制作防水涂料。现在你可能在想，就像我现在一样！这项活动似乎不适合该年级，但学校对此感到自豪，因为学生们使用了学校的实验室空间，还参与了动手学习活动。

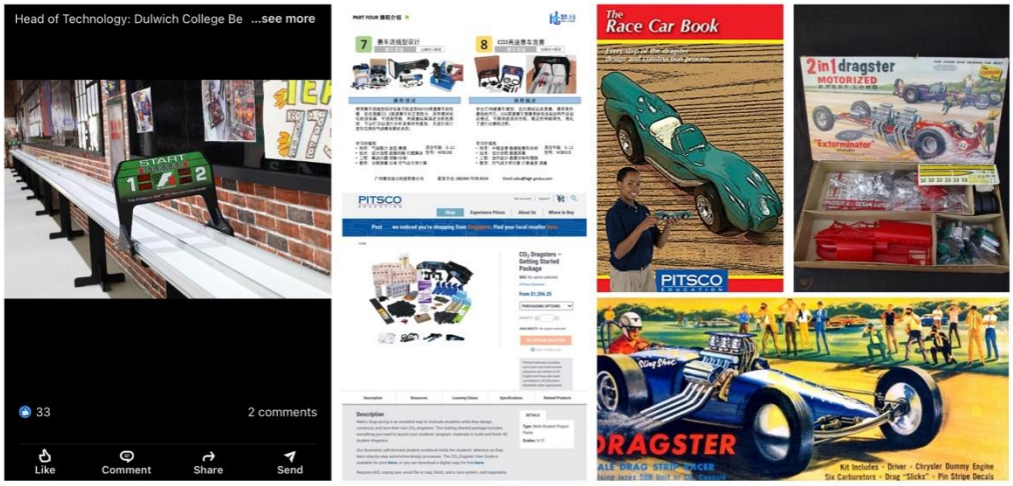
Now here are some more images from that post and you can see that these grade 12 students are in a well-equipped chemistry lab creating paint using "**craft glue**" and ground up "***coloured chalk***". But we are probably asking ourselves…. "***Where is the real chemistry?***" That being said, designing authentic STEM lessons is an incredibly difficult task. Especially if a teacher has never work in industry before! Now I should state that this teacher was amazing at teaching theoretical concepts. However, they had a limited understanding of how science was being used by industry professionals. Now there are so many ways that we could have made this project more appropriate for grade 12 students!	现在，这里有更多来自该帖子的图片，你可以看到这些 12 年级的学生在一个设备齐全的化学实验室里，用"工艺胶水"和磨碎的"彩色粉笔"创作油漆。但我们可能在问自己…。"真正的化学反应在哪里？" 话虽如此，设计真正的 STEM 课程是一项极其艰巨的任务。尤其是如果一个老师以前从未在这个行业工作过！现在我应该指出，这位老师在教授理论概念方面非常出色。然而，他们对行业专业人士如何使用科学的了解有限。 现在有很多方法可以让这个项目更适合 12 年级的学生！



So here I have some examples of what we could have done instead. Here on the left I have reference to how we could use chemical compounds that would allow for a "***thermochromic***" effect to be explored. That is when the colour of something changes because of a reversable chemical reaction due to changes in temperature. Next on the right I have an example of how you can create "***Ferric Oxide***" to create a colour pigment, and as we have already seen, "***ferric oxide***" has numerous applications in cosmetics and intertrial paints. Therefore, we already have a few options that we could use to improve this one project. **But let's take this a little bit further!** Now that we have some pigments, we can then explore different chemical methods to convert this pigment into a usable paint. First, we could look at how to use different chemical solutions to create a binding agent and chemical solvents. Alternatively, we could look to our past to learn how some of the greatest minds of our time created	因此，这里我有一些我们本可以做的例子。 在左边，我提到了我们如何使用化合物来探索"热致变色"效应。也就是说，由于温度变化引起的可逆化学反应，某种东西的颜色发生了变化。 在右边的下一个例子中，我有一个如何制造"氧化铁"来制造彩色颜料的例子，正如我们已经看到的，"氧化铁"在化妆品和涂料中有很多应用。因此，我们已经有了一些可以用来改进这个项目的选项。 但让我们更进一步！ 现在我们有了一些颜料，我们可以探索不同的化学方法将这种颜料转化为可用的油漆。首先，我们可以研究如何使用不同的化学溶液来制造结合剂和化学溶剂。或者，我们可以回顾我们的过去，了解我们这个时代一些最伟大的头脑是如何创造出杰作的，比如"西斯廷教堂"。当时，油漆是用"氧化铁"和"青金石"等颜料制成的，这些颜料被研磨成细粉末。然后将这些色素与蛋清混合，形成一种分子稳定的有机化合物，这种化合物可以持续几个世纪。

masterpieces such as the "**Sistine Chapel**". At this point in time paints were made using pigments such as "***ferric oxide***" and "***lapis lazuli***" which were ground into a fine powder. These pigments were then mixed with ***egg whites*** to create a ***molecularly stable***, ***organic compound*** that could last for centuries. So, with a few simple changes this project could easily be redesigned in a way that would make it much more meaningful.	因此，只要做一些简单的更改，这个项目就可以很容易地重新设计，使其更有意义。

Chemistry In STEM Education



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Next, I want to talk about fads vs. enduring knowledge, or more specifically looking at developing sustainable curriculums that can withstand the test of time.

Here I have a post showcasing a project that I personally really like… CO_2 dragsters! And this is one of the best-selling STEM project kits from High-Genius and PITSCO, b**ut this one product has been sold in the US for close to 70 years now!** Well before STEM ever existed!

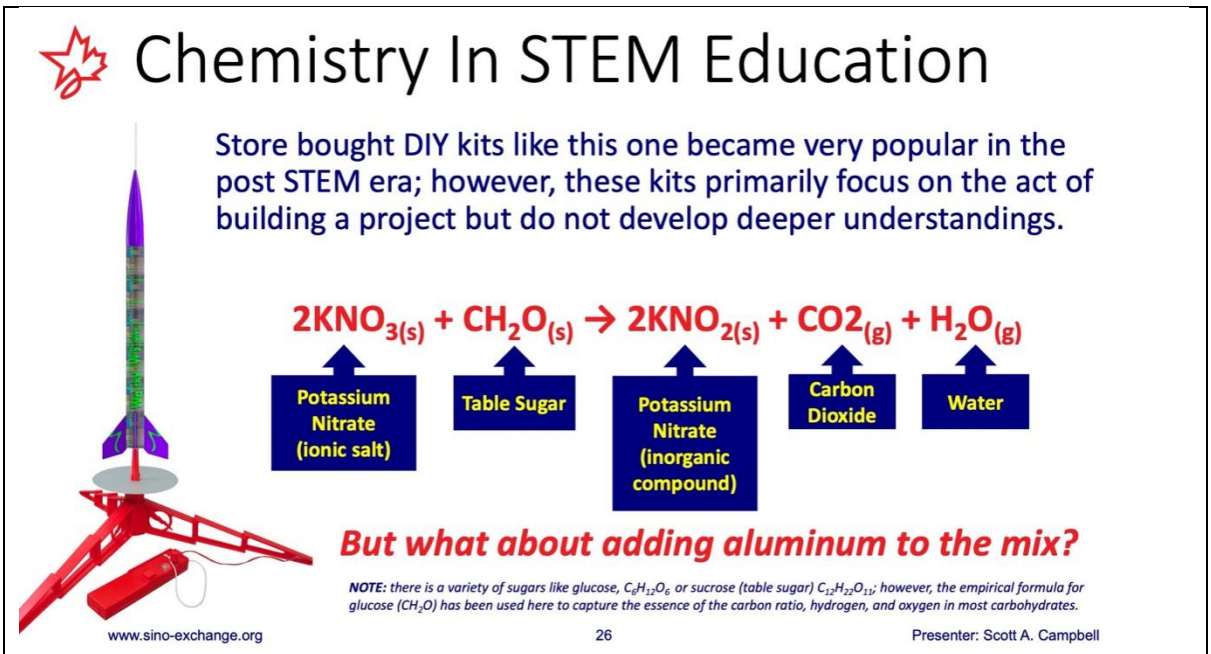
For example, here is the PITSCO guide to education from the 1990's, but CO2 racers were popular way before then! In these final examples you can see some of the kits from the mid 1950's, which were popular activities at the time as they helped get kids interested in aerodynamics and propulsion during the US-Soviet space race.

接下来，我想谈谈时尚与持久知识，或者更具体地说，是关于开发经得起时间考验的可持续课程。

在这里，我有一个帖子展示了一个我个人非常喜欢的项目…二氧化碳拖动器！这是 High Genius 和 PITSCO 最畅销的 STEM 项目套件之一，但这一产品在美国已经销售了近 70 年！早在 STEM 存在之前！

例如，这是 20 世纪 90 年代 PITSCO 的教育指南，但在那之前，二氧化碳赛车很受欢迎！在这些最后的例子中，你可以看到一些 20 世纪 50 年代中期的套件，这些套件在当时很受欢迎，因为它们帮助孩子们在美苏太空竞赛中对空气动力学和推进感兴趣。

Now we can see the influence of this idea of rocket propelled vehicles as a major driving force in our modern society even to this day. From development of the fastest land-based vehicle (which was essentially a rocket on wheels), to our modern-day mag-lev train technologies. All these advancements came from the study propulsion and aerodynamics.	现在，我们可以看到，即使到今天，火箭推进车辆作为我们现代社会的主要驱动力的这种想法的影响。从开发最快的陆基车辆（本质上是一枚带轮子的火箭），到我们现代的磁悬浮列车技术。所有这些进步都来自于对推进和空气动力学的研究。



Which brings me to my next example. While over the counter DIY kits provide educators with easy ready-made projects that can be implemented with little to no preparation.

These kits tend to offer very little towards achieving the desired learning outcomes of established curriculums. However, rocketry has so many wonderful grade-level extensions for students in an upper year's science program. For example:

$2KNO_3 + CH_2O \rightarrow 2KNO_2 + CO_2 + H_2O$

Here is a balanced chemical equation for a combustion-based reaction that students can use to make rocket fuel.

Now let me explain what is happening. First, we have ***potassium nitrate*** or fertilizer, which is mixed with ***regular table sugar***. Providing this chemical mixture does not encounter a flame it will remain relatively stable; however, it's capable of creating a powerful reaction that will create a large amount of thrust. This reaction will result in the formation of an ***inorganic compound***, ***carbon dioxide***, and ***water***.

这就引出了我的下一个例子。
而现成的 DIY 工具包为教育工作者提供了简单现成的项目，这些项目可以在几乎没有准备的情况下实施。

这些工具包在实现既定课程的预期学习成果方面往往收效甚微。然而，火箭技术为高年级科学项目的学生提供了许多精彩的年级扩展。例如：

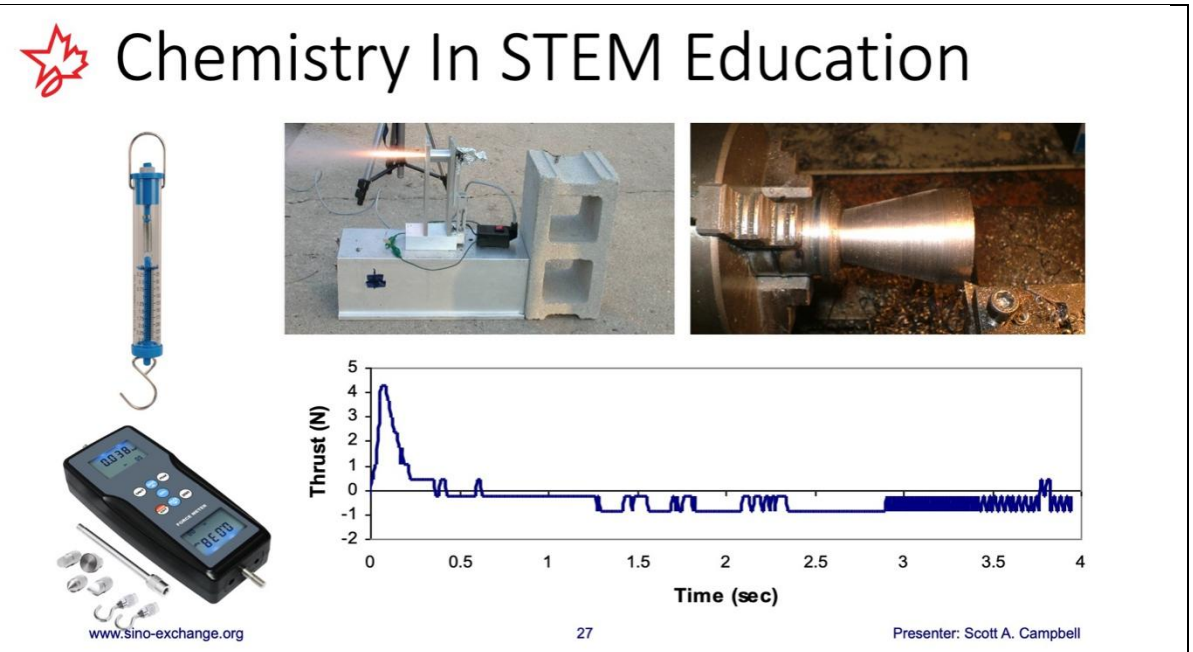
$2KNO_3 + CH_2O \rightarrow 2KNO_2 + CO_2 + H_2O$

这是一个基于燃烧的反应的平衡化学方程式，学生可以用来制造火箭燃料。

现在让我解释一下发生了什么。首先，我们有硝酸钾或肥料，它与普通食糖混合。如果这种化学混合物不遇到火焰，它将保持相对稳定；然而，它能够产生强大的反作用力，从而产生大量的推力。该反应将导致无机化合物、二氧化碳和水的形成。

Now as an instructor I wouldn't give my student the balanced chemical equation. Instead, I would start with a review, and then have my students balance this equation on their own before checking their work and moving on. Then, in-order to create the most efficient rocket fuel, the students would need to determine the ***molar mass*** of each compound in-order to determine the ***correct ratio*** for the entire mixture. With the math completed, the students would then be ready to create their own rocket fuel. Now as it stands this project would have them apply chemistry in an authentic way. However, it still wouldn't have the students apply the scientific method. And I have a perfect way to do that! What would happen if you added aluminum to the mix? Would it improve your rockets performance? And what evidence can you provide to support your claim? In this case students would need to formulate a hypothesis that we could go on and test. Now in theory adding something that is not necessary to balance the chemical reaction is ill-advised; however, adding aluminum to solid rocket fuel is a unique exception to that rule. **Let me tell you a bit more about this pheromone.** In the early 1950's Keith Rumbel and Charles Henderson conducted a series of experiment where they added aluminum to conventional solid rocket fuels. The results of their experiments indicated a dramatic increase in the exit velocity of the combustion gases. This new chemical formulation was so powerful, it was able produce similar levels of	现在，作为一名教师，我不会给我的学生一个平衡的化学方程式。 相反，我会从复习开始，然后让我的学生在检查他们的工作并继续前进之前，自己平衡这个方程。然后，为了制造出最有效的火箭燃料，学生们需要确定每种化合物的摩尔质量，以确定整个混合物的正确比例。完成数学运算后，学生们就可以制造自己的火箭燃料了。 现在，这个项目将让他们以一种真实的方式应用化学。 然而，它仍然不会让学生应用科学的方法。我有一个完美的方法来做到这一点！ 如果你在混合物中加入铝，会发生什么？ 它会提高你的火箭性能吗？ 你能提供什么证据来支持你的主张？ 在这种情况下，学生们需要制定一个假设，我们可以继续测试。现在理论上，添加一些不必要的东西来平衡化学反应是不明智的；然而，在固体火箭燃料中添加铝是该规则的一个独特例外。 让我告诉你更多关于这种信息素的信息。20 世纪 50 年代初，Keith Rumbel 和 Charles Henderson 进行了一系列实验，在常规固体火箭燃料中添加铝。他们的实验结果表明，燃烧气体的出口速度显著增加。这种新的化学配方非常强大，能够产生与煤油和液态 O2 等液体燃料类似的性能！因此，由于他们研究的独特性，美国海军能够大幅增加弹道导弹和轨道火箭的射程。

performance to liquid fuels such as ***kerosene*** and ***liquid O_2***! Therefore, due to the unique nature of their research, the US Navy was able to significantly increase the range of ballistic missiles and orbital rockets. Now because this was a bit of a trick question, almost every student's hypothesis will be disproven. However, this will give them a great opportunity to conduct some internet research look for answers. But how would we test their hypothesis?	现在，因为这是一个有点技巧的问题，几乎每个学生的假设都会被推翻。然而，这将给他们一个很好的机会进行一些互联网研究，寻找答案。 但我们该如何检验他们的假设呢？



Using a simple analog force gauge, we can test the amount of thrust produced by each rocket. Or for a bit more accuracy we can use a digital force meter to easily record and export precise data from our experiments directly to the computer.

Now you can see what a simple set up for testing home-made rocket engines would look like in this photo. And finally, if your school has a metal shop you may also consider manufacturing your own custom designed rocket engines using a small metal lathe.

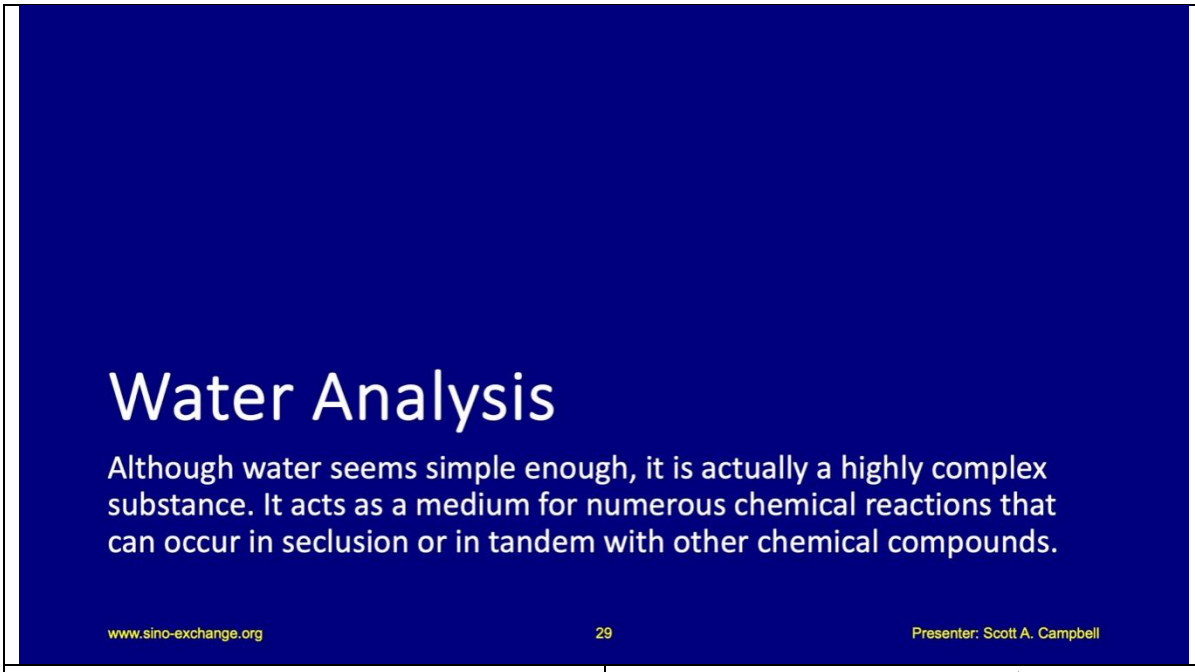
As you can see from this example, when you develop a fully cross-circular approach to teaching and learning – which is what should be happening in STEM – your projects will go much deeper into the core curriculum. And this type of in-depth and insightful exploration. That's what is going to make students more competitive in the new global economy!

使用一个简单的模拟力计，我们可以测试每枚火箭产生的推力。或者，为了获得更高的精度，我们可以使用数字测力计轻松地记录实验中的精确数据，并将其直接导出到计算机。

现在你可以看到这张照片中测试自制火箭发动机的简单设置是什么样子的。最后，如果你的学校有一家金属店，你也可以考虑用一台小型金属车床制造自己定制的火箭发动机。

正如你从这个例子中看到的那样，当你开发出一种完全跨循环的教学方法时——这是 STEM 中应该发生的事情——你的项目将深入到核心课程中。而这种类型的深入而富有洞察力的探索。这将使学生在新的全球经济中更有竞争力！

And that brings us to Big Idea #3, where I would like to share some specific examples of how chemistry is used to solve real-world problems, and how we can use these examples to create authentic lessons that apply chemistry in an appropriate real-world context.	就引出了大创意#3，我想在这里分享一些关于化学如何被用来解决现实世界问题的具体例子，以及我们如何利用这些例子来创建真实的课程，将化学应用于适当的现实世界环境中。



The first real-world example that I would like to share with you is related to analyzing water samples. Now water seems simple enough; however, it's actually a highly complex substance. This is because water acts as a medium for numerous chemical reactions that can occur in tandem with other chemical reactions as you will see in just a moment.	我想和大家分享的第一个真实世界的例子与分析水样有关。现在水似乎已经足够简单了；然而，它实际上是一种高度复杂的物质。这是因为水是许多化学反应的介质，这些化学反应可以与其他化学反应同时发生，正如你稍后看到的那样。

Chemistry In STEM Education

While most people are only aware of simple over the counter test solutions, commercial testing requires a much more sophisticated approach to water analysis.

Test strips:
- Limited metrics;
- Lack precision;
- Results can be easily skewed;
- Do not show the correlation between how different metrics interact with one another.

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Students are often taught how to use test strips like these, or litmus paper in class. however, commercial water tests require a more accurate and sophisticated approach to testing a sample, and personally, I don't recall a single time where I used test strips while working in industry.

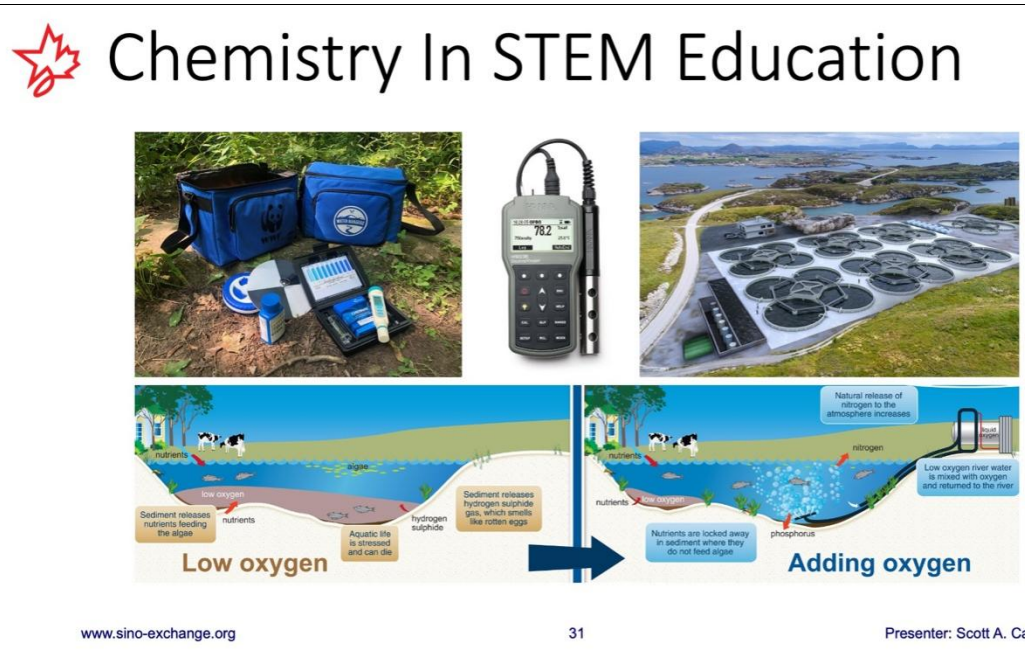
This is because test stripes:
- Only measure key metrics
- While lacking precision
- The results can be easily skewed.
- And test strips do not show the relationship or correlation between different metrics.

Therefore, all these factors make test strips relatively unreliable. While they are perfectly fine for teaching the basics in controlled situation, outside of the classroom test strips have limited to no real-world value.

学生们经常被教导如何在课堂上使用像这样的试纸或石蕊试纸。然而，商业水测试需要一种更准确、更复杂的方法来测试样本，就我个人而言，我不记得我在行业工作时曾使用过测试条。

这是因为测试条纹：
- 仅测量关键指标
- 缺乏精度
- 结果很容易出现偏差。
- 测试条没有显示不同指标之间的关系或相关性。

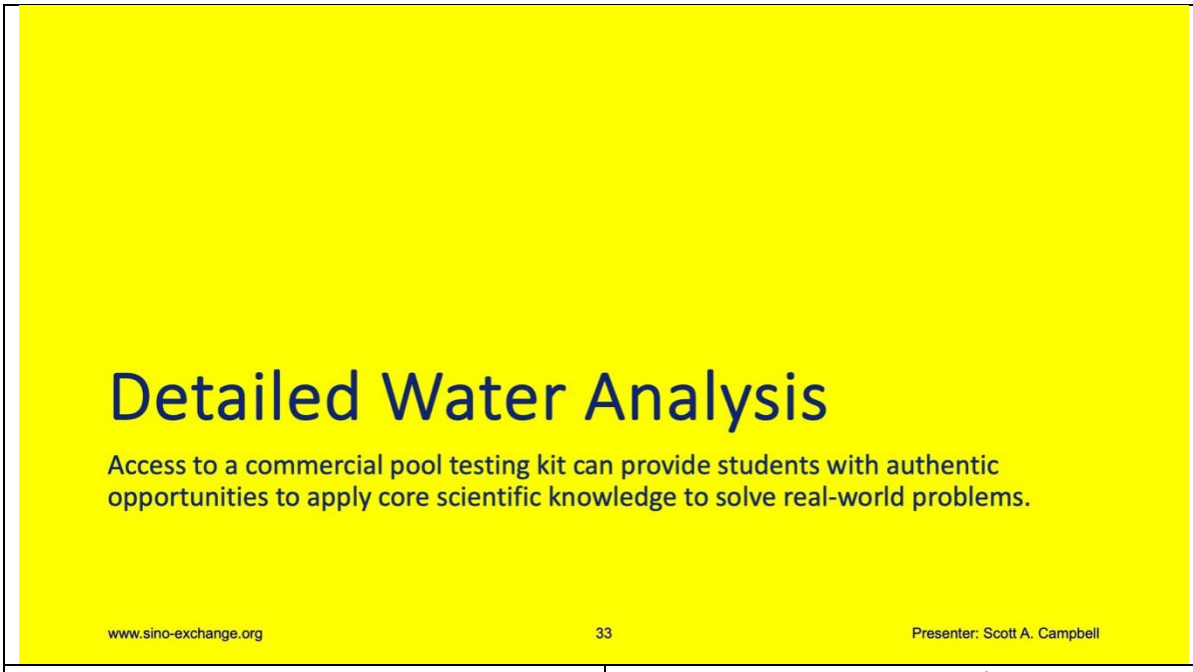
因此，所有这些因素使得测试条相对不可靠。虽然它们非常适合在受控的情况下教授基础知识，但课堂外的测试条在现实世界中没有任何价值。



Therefore, field chemists will often use professional testing reagents or digital meters to collect accurate and precise readings. For instance, experienced environmental engineers and will often conduct tests using specialized "***dissolved oxygen test kit***" which use very specific chemical reagents. Alternatively, things like this digital dissolved oxygen meter may also be used, and many schools already have PASCO or VERNIER lab equipment in their school's science labs which students could use to conduct similar tests for themselves. And these kinds of water test are critical to the preservation of the hydrological-cycles, and the management of our fresh water supply.	因此，现场化学家会经常使用专业的检测试剂或数字仪表来收集准确、精确的读数。例如，经验丰富的环境工程师经常使用专门的"溶解氧测试试剂盒"进行测试，该试剂盒使用非常特殊的化学试剂。 或者，也可以使用这种数字溶解氧计，许多学校的科学实验室已经有 PASCO 或 VERNIER 实验室设备，学生可以使用这些设备进行类似的测试。这些类型的水测试对保持水文循环和管理淡水供应至关重要。

And to illustrate this idea, here is a photo I took on my last trip to Yunnan province in China. One thing that caught my attention during my trip were these devices. They were being used to increase the amount of dissolved oxygen in the lake water which was reducing the number of toxic algae blooms and helping the aquatic life thrive. As a result, the water quality in these lakes has drastically improved over the years to what you see today. Crystal clear blue lakes. Now this would be a perfect STEM project for students to undertake. Design, build, and test a water oxidation device. However, this project would be more in line with engineering practices than chemical testing applications. For instance, testing dissolved oxygen is relatively simple with a digital meter. however, what makes environmental engineering demanding is the continual testing and follow up. For instance, the technician or engineer would need to test the oxygen levels for an extended period of time. In the case of this environmental project	为了说明这个想法，这里有一张我上次去中国云南省旅行时拍的照片。 在旅途中，有一件事引起了我的注意，那就是这些设备。它们被用来增加湖水中的溶解氧含量，从而减少有毒藻类的数量，帮助水生生物茁壮成长。因此，这些年来，这些湖泊的水质已经大幅改善，达到了今天的水平。清澈的蓝色湖泊。 现在，对于学生来说，这将是一个完美的 STEM 项目。设计、建造和测试水氧化装置。然而，与化学测试应用相比，该项目更符合工程实践。 例如，用数字仪表测试溶解氧相对简单。然而，环境工程的要求是不断的测试和跟进。例如，技术人员或工程师需要长时间测试氧气水平。 就云南的环保项目而言，当我访问该县

Yunnan, it had already been going on for 10 years when I had visited the county. As such, this kind of data collection and analysis isn't practical for a high-school lab. Therefore, we need to look for something that has more immediate results. Luckily enough, many schools have access to a great resource that they can use to conduct some real-world water analysis that is probably far more relevant to the student's everyday life.	时，它已经进行了 10 年。因此，这种数据收集和分析对于高中实验室来说是不现实的。因此，我们需要寻找更直接的结果。 幸运的是，许多学校都能获得大量资源，可以用来进行一些现实世界中的水分析，这些分析可能与学生的日常生活更为相关。



Many private schools that I have visited have their own swimming pool, or at the very least have access to tap water that they could test.

Now if your school has access to a swimming pool the students can test the water, identify any potential problems, and then determine what corrective measures would be necessary to properly balance the pool water. However, if your school does not have access to a swimming pool, you can still test regular tap water to determine the suitability of a water source for use in a commercial swimming pool. In this situation you would still need to analyze what treatment options would be necessary to optimize or balance the water before it could be used.

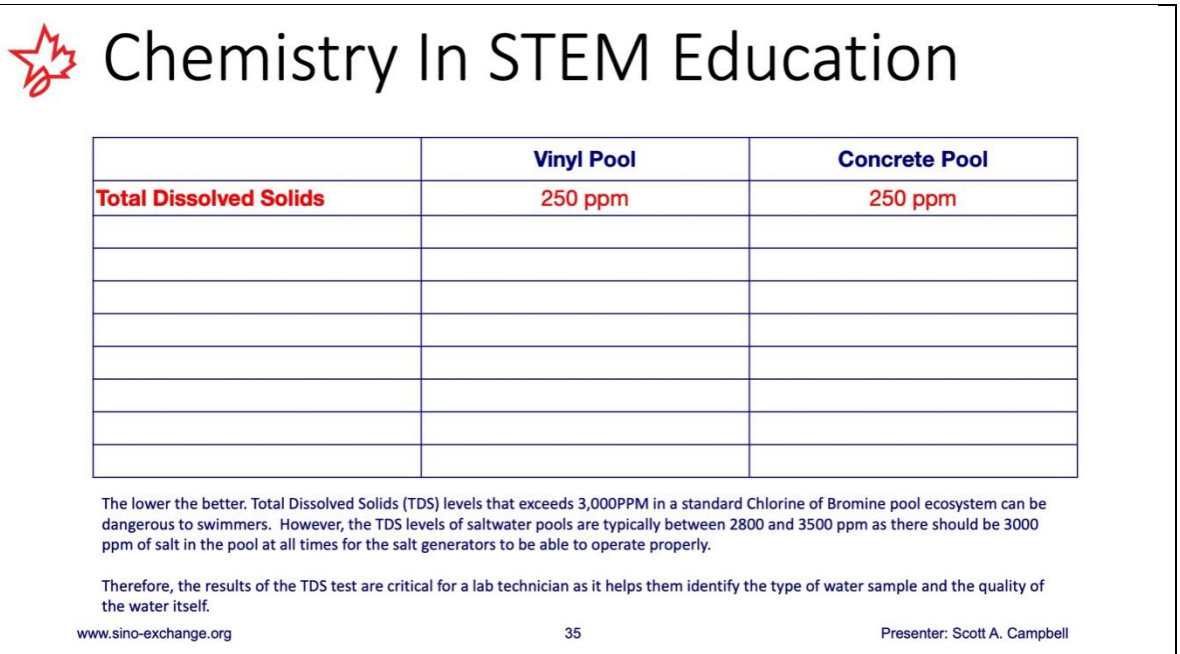
Either way, the students will be able to conduct a wide range of experiments to test a water sample and analyze the results. However, I should warn you, although most people think that testing pool water is a simple task – It's actually quite demanding as you will see in a moment.

我去过的许多私立学校都有自己的游泳池，或者至少可以使用自来水进行测试。

现在，如果你的学校可以使用游泳池，学生们可以测试池水，找出任何潜在的问题，然后确定需要采取哪些纠正措施来适当平衡池水。然而，如果你的学校没有游泳池，你仍然可以测试常规自来水，以确定水源是否适合在商业游泳池使用。在这种情况下，在使用之前，您仍然需要分析优化或平衡水所需的处理方案。

无论哪种方式，学生都将能够进行广泛的实验来测试水样并分析结果。然而，我应该警告你，尽管大多数人认为测试池水是一项简单的任务——正如你稍后将看到的那样，它实际上要求很高。

As I mentioned before, test strips are not particularly useful as they lack precision. Therefore, the results that you get from test strips can be easily skewed. That is why commercially operated pools are required to conduct professional water tests on a regular basis. In this example I am showing a lab set-up from ***Bio-Guard*** which is a company that I have I lot of experience working with. However, other companies such as: Lamottee, Taylor Technologies, and Fishersci also provide commercial testing solutions for commercial pools. Now as you can see by this lab set-up, testing pool water to meet health and safety regulations is no joke! It's a serious task. So let me take a moment to explain the different test that must be conducted by the lab technician.	正如我之前提到的，测试条并不是特别有用，因为它们缺乏精度。 因此，你从测试条中得到的结果很容易被扭曲。这就是为什么商业运营的游泳池需要定期进行专业的水测试。 在这个例子中，我展示了 Bio-Guard 的实验室设置，这是一家我有很多工作经验的公司。然而，Lamottee、Taylor Technologies 和 Fishersci 等其他公司也为商业游泳池提供商业测试解决方案。现在，正如你从这个实验室设置中看到的那样。测试池水以满足健康和安全规定可不是闹着玩的！这是一项艰巨的任务。 因此，让我花点时间解释一下实验室技术人员必须进行的不同测试。



The first test is to determine the amount of "***Dissolved Solids***" or **TDS**.

Using a **TDS** meter, the conductivity of dissolved ions is tested. This is done by sending out a small electrical charge through the sample to measure the "**electrical conductivity**" of the solution in what is called "***siemens***". If you are unfamiliar with the term "***siemens***", it is the SI unit of conductance and is equal to "***one reciprocal ohm***". Now ideally the lower the TDS level the better!

However, it's also important to note that not all pools use chlorine as a sanitizing agent. Some pools, particularly in Australia, use salt instead and this will affect the TDS level of the water.

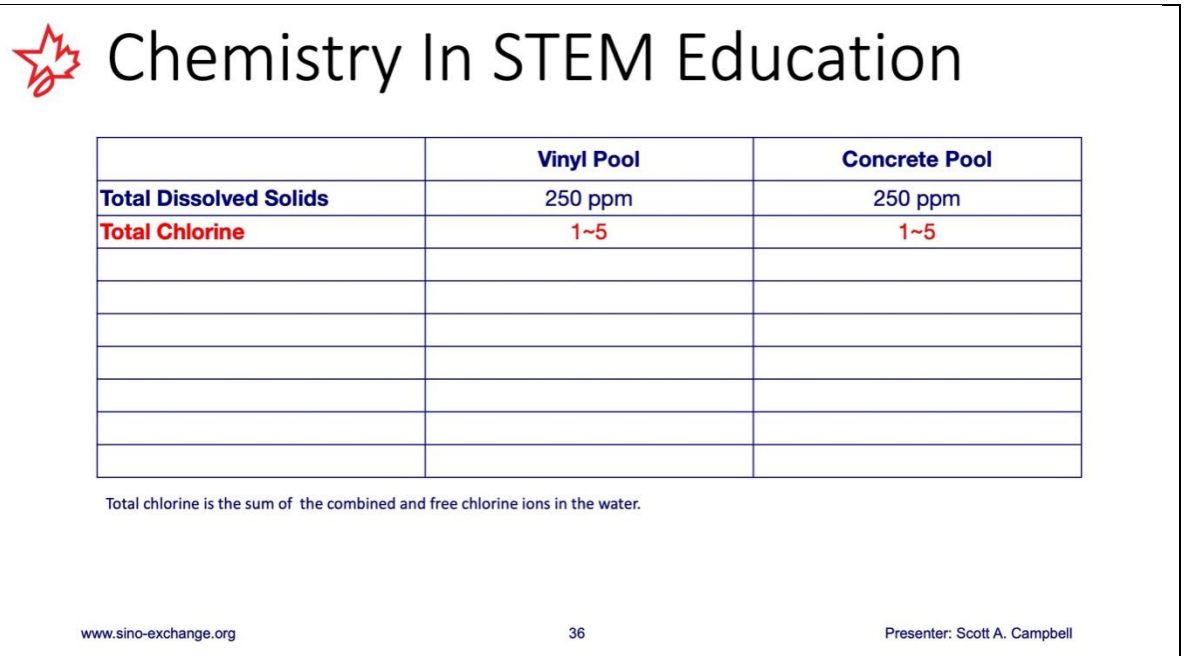
Regardless of the sanitizing agent being used… testing the TDS level of the pool is an important step in determining the overall quality of the water sample.

第一项测试是确定"溶解固体"或 TDS 的含量。

使用 TDS 计测试溶解离子的电导率。这是通过在样本中发出少量电荷来测量所谓"西门子"溶液的"电导率"来实现的。如果你不熟悉"西门子"这个词，它是电导的国际单位制，等于"一倒数欧姆"。现在，理想情况下，TDS 水平越低越好！

然而，同样重要的是要注意，并不是所有的游泳池都使用氯作为消毒剂。一些游泳池，特别是在澳大利亚，使用盐代替，这将影响水的 TDS 水平。

无论使用哪种消毒剂……测试水池的 TDS 水平是确定水样整体质量的重要步骤。



The next test is for "***Total Chlorine***" and typically uses 10ml water sample. A reagent which will change colour depending on the concentration of chlorine is added to the water sample. That sample is then held against a white backlight and is compared against an accurate colour chart. With Bio-guard the regent comes a premeasured tablet which is then dissolved in the sample. This ensures that the addition of the reagent is perfectly measured every time. However, other companies such as Taylor use a liquid reagent which is a little bit easier to use in high-volume situations. That being said, the droplet size can vary slightly depending on how hard you squeeze the reagent bottle.	下一个测试是"总氯"，通常使用 10ml 水样。将一种根据氯浓度而变色的试剂添加到水样中。然后将该样品保持在白色背光下，并与精确的颜色表进行比较。在 Bio-guard 中，试剂是一种预先测量的片剂，然后将其溶解在样品中。这确保了每次都能完美地测量试剂的添加量。然而，Taylor 等其他公司使用的液体试剂在大容量情况下更容易使用。也就是说，液滴的大小可能会略有不同，这取决于你挤压试剂瓶的力度。

Chemistry In STEM Education

	Vinyl Pool	Concrete Pool
Total Dissolved Solids	250 ppm	250 ppm
Total Chlorine	1~5	1~5
Free Chlorine	1~5	1~5

The total and free chorine values should match. A discrepancy between these values indicates a problem with the pool water. Free chlorine refers to chlorine that is present as hypochlorous acid (HOCl) or as a hypochlorite (OCl –) ion. When the chlorine demand of water is satisfied, free chlorine is available to oxidize contaminants. Whereas combined chlorine exists in chemical combination with ammonia or other organic (nitrogen based) compounds rendering it useless.

***NOTE:** high chlorine values result in test strips getting bleached which skews the results. Thus, making test strips unreliable for commercial testing applications.*

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The next test is for "***Free Chlorine***". Now both ***total and free chlorine*** tests should be done simultaneously so that the values can be compared. Ideally these two values should match. however, there are numerous situation which can cause a discrepancy. These scenarios would indicate a serious problem with the pool water that needs to be addressed. Furthermore, if either of the chlorine levels exceeds 5ppm the results of the other tests will be skewed. While professional tests using reagents and neutralizers can accommodate for this, a generic test-strip cannot deal with this issue.

下一个测试是"游离氯"。现在，总氯和游离氯的测试应该同时进行，以便可以比较这些值。理想情况下，这两个值应该匹配。然而，有许多情况会导致差异。这些情况表明池水存在严重问题，需要加以解决。此外，如果其中一个氯含量超过 5ppm，则其他测试的结果将出现偏差。虽然使用试剂和中和剂的专业测试可以适应这种情况，但通用测试条无法解决这个问题。

Chemistry In STEM Education

	Vinyl Pool	Concrete Pool
Total Dissolved Solids	250 ppm	250 ppm
Total Chlorine	1~5	1~5
Free Chlorine	1~5	1~5
pH	7.4 ~ 7.6	7.4 ~ 7.6

The optimum pH for a pool is 7.5 as this is the same pH as the mucous membrane in the human eye (this is the most sensitive part of the human body that is exposed to external environmental factors), and all other aspects of the pool have been designed to function optimally at this pH; moreover, the effectiveness of choline as a sanitizer is optimal when the pH of the pool is within the desired range.

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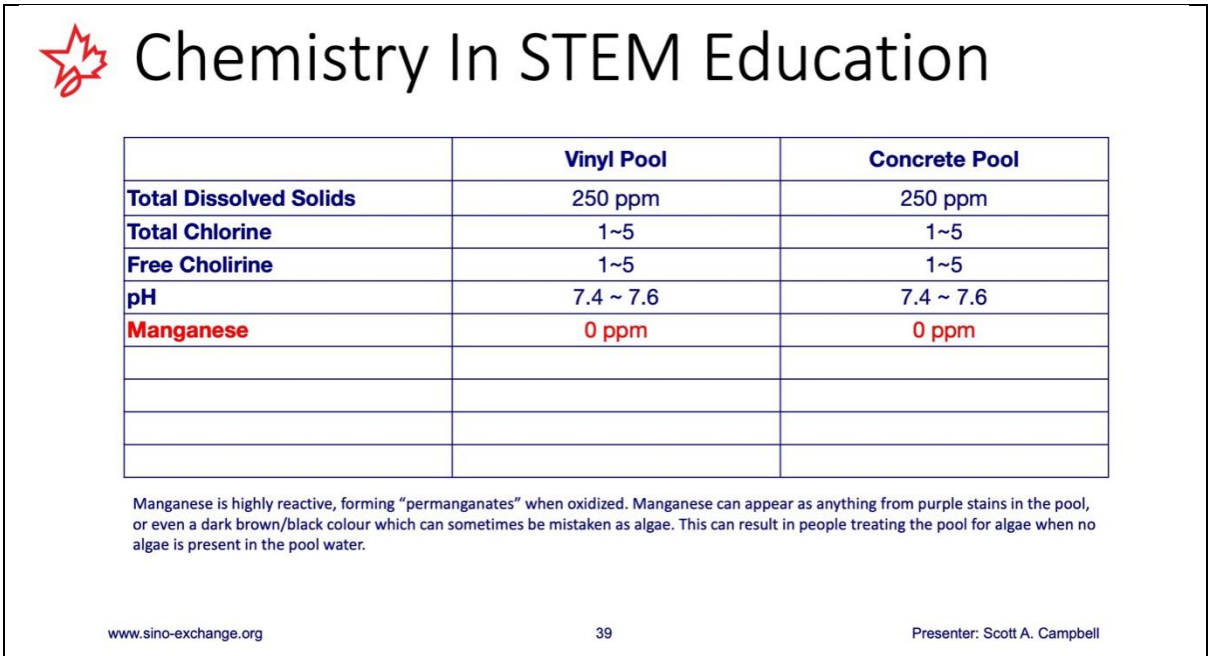
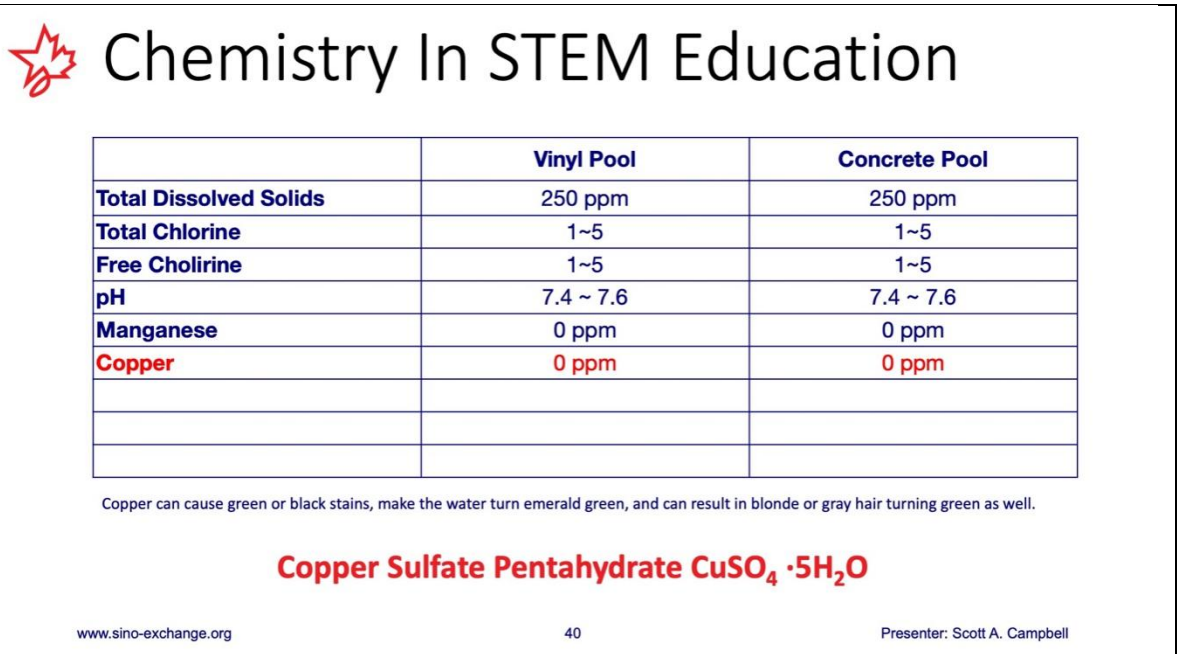
The next test that needs to be done is pH. Now if the chlorine value exceeds 5ppm you can get a phenomenon called "***bromafidal blue***". In this case the pH reagent turns a dark purple which would indicate a very high pH. However, in these situations the pH is usually very low. Therefore, it's easy to misinterpret the results of the test and recommend the wrong treatment to address the problem. That said, if you know that the chlorine level is high before conducting your pH test you can act accordingly. All you need to do is add chlorine neutralizer to the water sample before adding "**phenol red"** to test the pH level of the water sample.	下一个需要做的测试是 pH。现在，如果氯值超过 5ppm，就会出现一种称为"溴代蓝"的现象。在这种情况下，pH 试剂会变成深紫色，这表明 pH 非常高。然而，在这种情况中，pH 通常非常低。因此，很容易误解测试结果，并建议采取错误的处理方法来解决问题。也就是说，如果你在进行 pH 测试之前知道氯含量很高，你可以采取相应的行动。你所需要做的就是在加入"酚红"之前向水样中加入氯中和剂，以测试水样的 pH 值。



The next test that is for ***"manganese"*** which can cause damage to the surface of a pool.	下一个测试是"锰"，它会对游泳池表面造成损坏。



After that, additional metals such as ***cooper"*** are then tested for.

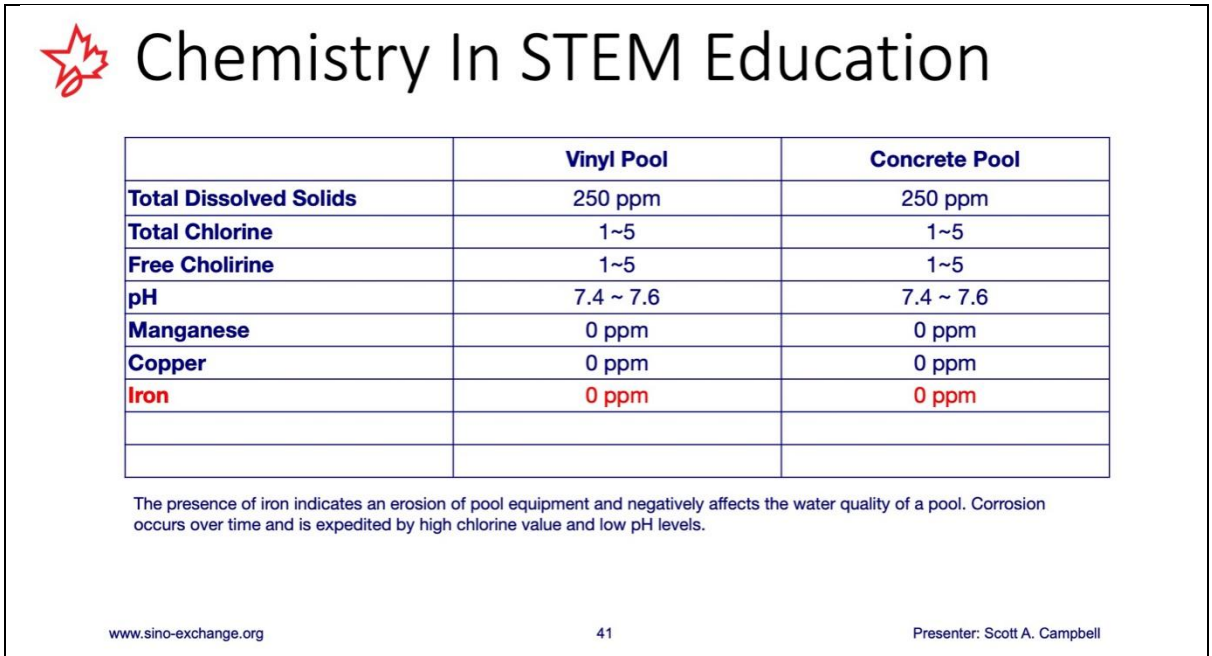
Now cooper can enter pool water in a few different ways. If the pH is low the acidity of the water can start corroding the pool equipment. however, this is becoming less common as most companies are now avoid using metals in places that are exposed to water. Alternatively, copper gets added by people all the time, particularly when a pool is being neglected by its owner.

In the event of a large algae bloom, many pool owners turn to ***Copper Sulfate*** which can be purchased at many department stores. While the addition of copper sulfate is an effective method to eliminate the algae, it does create a series of serious problems that need to be addressed before the pool can be used again.

然后，对铜等其他金属进行测试。

现在库珀可以通过几种不同的方式进入池水。如果 pH 值低，水的酸度可能会开始腐蚀游泳池设备。然而，这种情况越来越不常见，因为大多数公司现在都避免在暴露在水中的地方使用金属。或者，铜总是被人们添加，尤其是当游泳池被主人忽视时。

在藻类大量繁殖的情况下，许多池水所有者会选择这种可以在许多百货公司买到的硫酸铜。虽然添加硫酸铜是消灭藻类的有效方法，但它确实产生了一系列严重的问题，在水池再次使用之前需要解决这些问题。



And finally, the last metal that's tested for is ***"iron"***. Since this reagent smells like rotten eggs, you are likely going to have students complain about it if you do this test in a poorly ventilated classroom.	最后，最后一种被测试的金属是"铁"。由于这种试剂闻起来像臭鸡蛋，如果你在通风不良的教室里进行测试，你很可能会被学生抱怨。

Chemistry In STEM Education

	Vinyl Pool	Concrete Pool
Total Dissolved Solids	250 ppm	250 ppm
Total Chlorine	1~5	1~5
Free Cholirine	1~5	1~5
pH	7.4 ~ 7.6	7.4 ~ 7.6
Manganese	0 ppm	0 ppm
Copper	0 ppm	0 ppm
Iron	0 ppm	0 ppm
Total Alkalinity	100~150 ppm	8~120 ppm

Total alkalinity (TA) is the measure of the water's ability to neutralize acids. Alkaline compounds that are present in water, like hydroxides and carbonates, eliminate H+ ions from the water, which lowers the acidity of the water and results in a higher pH. Total alkalinity is gauged by measuring the level of acid that is required to reduce a certain sample's pH level to 4.2. At this level, all alkaline compounds are completely depleted. Measuring alkalinity is vital in identifying the capacity of water to neutralize the acidic and corrosive effects from wastewater and other sources, such as rainfall.

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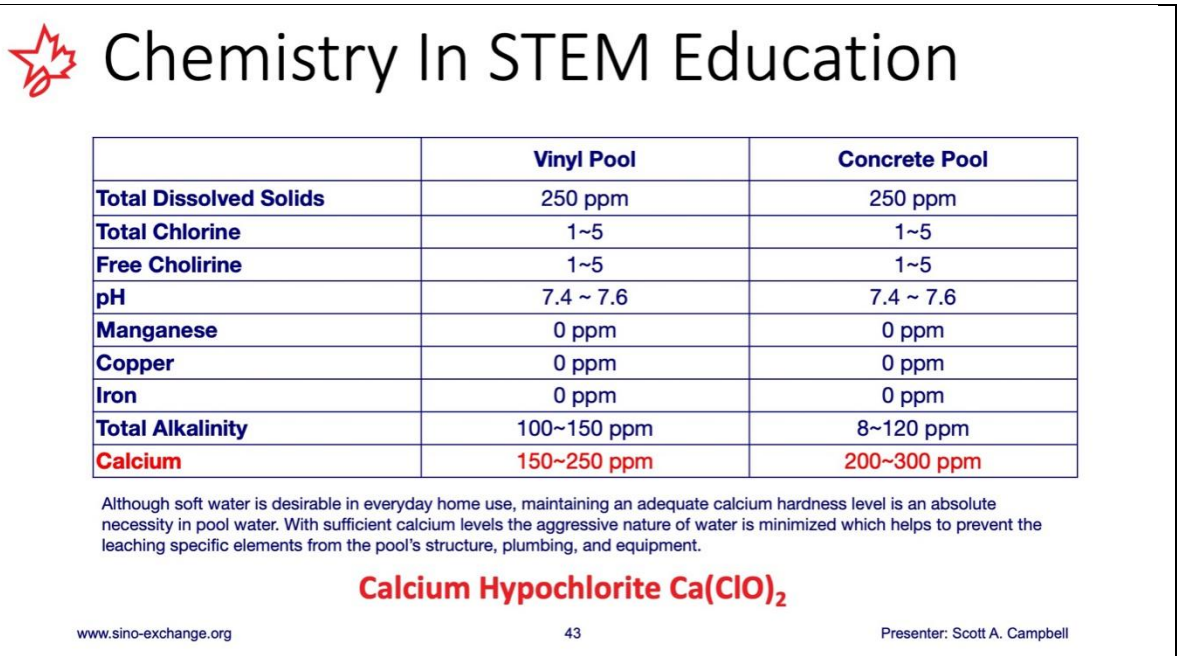
The next test in the series uses a chemical titration to determine the total alkalinity of the water sample. For this test you will measure 100ml of water using a graduated cylinder which will then be poured into a large beaker which has a volume no less than 250ml. Then using a ***magnetic stir-plate***, you can slowly stir the water sample during the titration.

Start with a slow flow of reagent at first until you start seeing a change in the colour. Then reduce the titration to a steady drip. Monitor the colour of the sample after every drip and the moment the sample changes from a bright yellow-orange to a dark orange color ***stop the titration!*** Then take a measurement from the burette to see how much reagent was used during the titration.

该系列的下一个测试使用化学滴定法来确定水样的总碱度。在本测试中，您将使用量筒测量 100 毫升水，然后将量筒倒入体积不小于 250 毫升的大烧杯中。然后使用磁性搅拌板，可以在滴定过程中缓慢搅拌水样。

首先从缓慢的试剂流开始，直到你开始看到颜色的变化。然后将滴定减少到稳定滴下。每次滴加后监测样品的颜色，当样品从亮黄色变为暗橙色时，停止滴定！然后从滴定管中进行测量，看看滴定过程中使用了多少试剂。



And the final test is to determine the "**calcium hardness**" of the water.

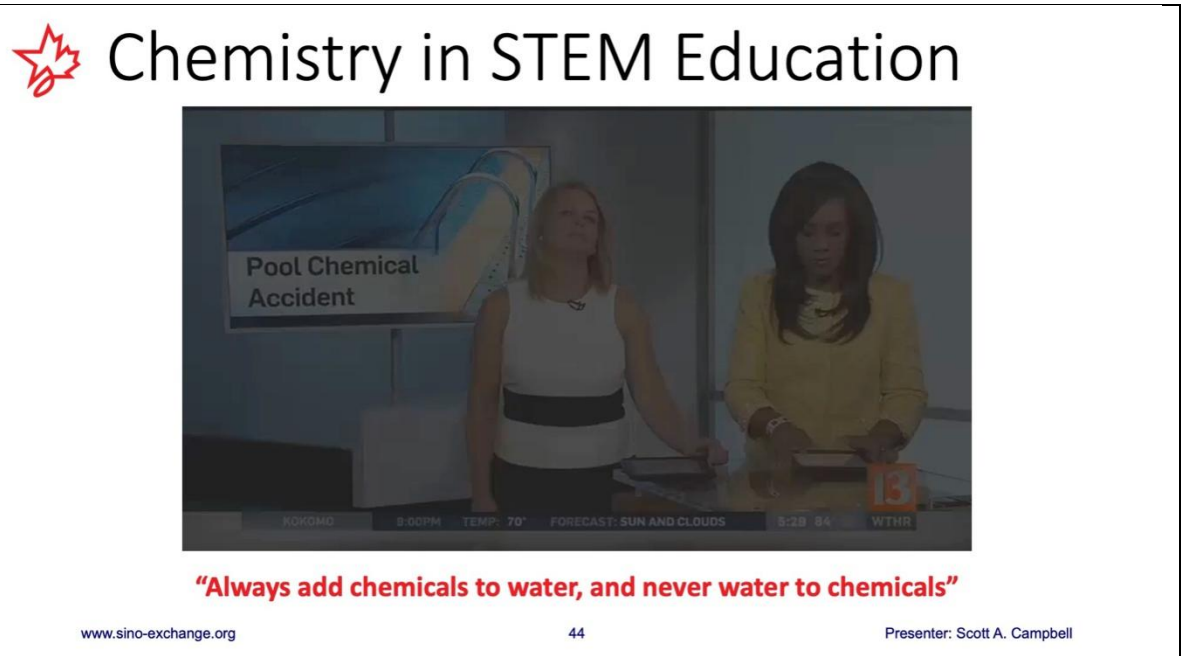
This test also a uses a chemical titration, but the reagents will go from a vibrant pink to a dark purple during this test. Now as there is no way to practically remove calcium from the water, the only way to address calcium hardness is by draining some of the existing water and adding soft water to replace it. Typically, the calcium level of the pool will be balanced when water is first added and is not adjusted unless a large amount of fresh water has just been added to the pool. However, the use of **Calcium Hypochlorite** can slowly affect the calcium hardness of the pool water over time.

This low-cost granular choline shock has a relatively low chlorine content per molecule, slow to dissolve, causes the water to go cloudy, and is molecularly unstable and this can lead to the compound spontaneously combusting. However, due to its relative low cost, many commercial operators like to use this low-cost product in their regular maintenance routines.

最后的测试是确定水的"钙硬度"。

这个测试也使用了化学滴定，但在这个测试过程中，试剂会从鲜艳的粉红色变成深紫色。现在，由于没有办法实际去除水中的钙，解决钙硬度问题的唯一方法是排出一些现有的水，并添加软水来代替它。通常，当第一次加水时，水池的钙水平会保持平衡，除非刚刚向水池中添加了大量淡水，否则不会进行调整。然而，随着时间的推移，使用次氯酸钙会慢慢影响池水的钙硬度。

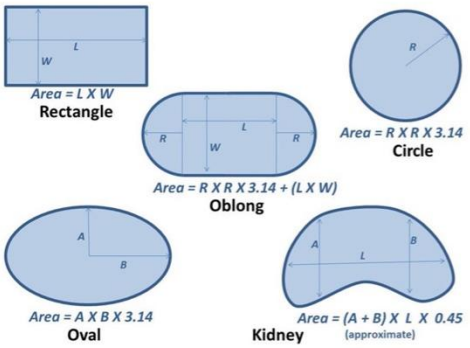
这种低成本的颗粒胆碱每分子氯含量相对较低，溶解缓慢，导致水浑浊，分子不稳定，这可能导致化合物自燃。然而，由于其相对较低的成本，许多商业运营商喜欢在日常维护中使用这种低成本的产品。



And that brings me to the idea of safety, and why it is important to understand chemistry. To avoid dangerous chemical reactions, like the one we saw in this short video you should never mix random chemicals together, and you should **"always add chemicals to water, and never water to chemicals".** Now I don't expect that you students would ever be adding chemicals to the school's swimming pool. however, this one safety tip is incredibly relevant to any experiment that you will do in the lab. And Finaly, while the dangers that chemicals such as **calcium hypochlorite $Ca(ClO)_2$** cannot be understated! There is another chemical that is commonly used by many pool owners use that is even more dangerous. This chemical is **sodium hypochlorite (NaClO),** which is more commonly known as ***liquid chlorine***. Furthermore, this chemical is often used in conjunction with ***hydrochloric acid (HCl)*** in many commercial pool setups. However, these two chemicals can result in violent explosions that will produce chlorine gas if	这让我想到了安全的概念，以及为什么理解化学很重要。 为了避免危险的化学反应，就像我们在这段短视频中看到的那样，你永远不应该把随机的化学物质混合在一起，你应该"总是在水中添加化学物质，永远不要在化学物质中加水"。 现在我没想到你们这些学生会在学校的游泳池里添加化学物质。然而，这一个安全提示与你将在实验室进行的任何实验都非常相关。 最后，化学物质如次氯酸钙 $Ca(ClO)_2$ 的危险不容低估！还有一种被许多泳池业主普遍使用的化学物质更危险。这种化学物质是次氯酸钠（NaClO），它通常被称为液氯。此外，在许多商业池设置中，这种化学品经常与盐酸（HCl）一起使用。然而，这两种化学物质可能会导致剧烈爆炸，如果意外混合，会产生氯气。现在仅供参考，这是大屠杀期间用来制造氯气的相同化学反应！

accidently mixed. Now for reference, this is the same chemical reaction that was used to create chlorine gas during the holocaust!	

Chemistry In STEM Education



23. Volume of water in a swimming pool A rectangular swimming pool is 30 ft wide and 50 ft long. The accompanying table shows the depth $h(x)$ of the water at 5-ft intervals from one end of the pool to the other. Estimate the volume of water in the pool using the Trapezoidal Rule with $n = 10$ applied to the integral

$$V = \int_0^{50} 30 \cdot h(x)\, dx.$$

Position (ft) x	Depth (ft) $h(x)$	Position (ft) x	Depth (ft) $h(x)$
0	6.0	30	11.5
5	8.2	35	11.9
10	9.1	40	12.3
15	9.9	45	12.7
20	10.5	50	13.0
25	11.0		

***NOTE:** the pool needs to be balanced in the same order that we conducted the tests on the original water sample.*

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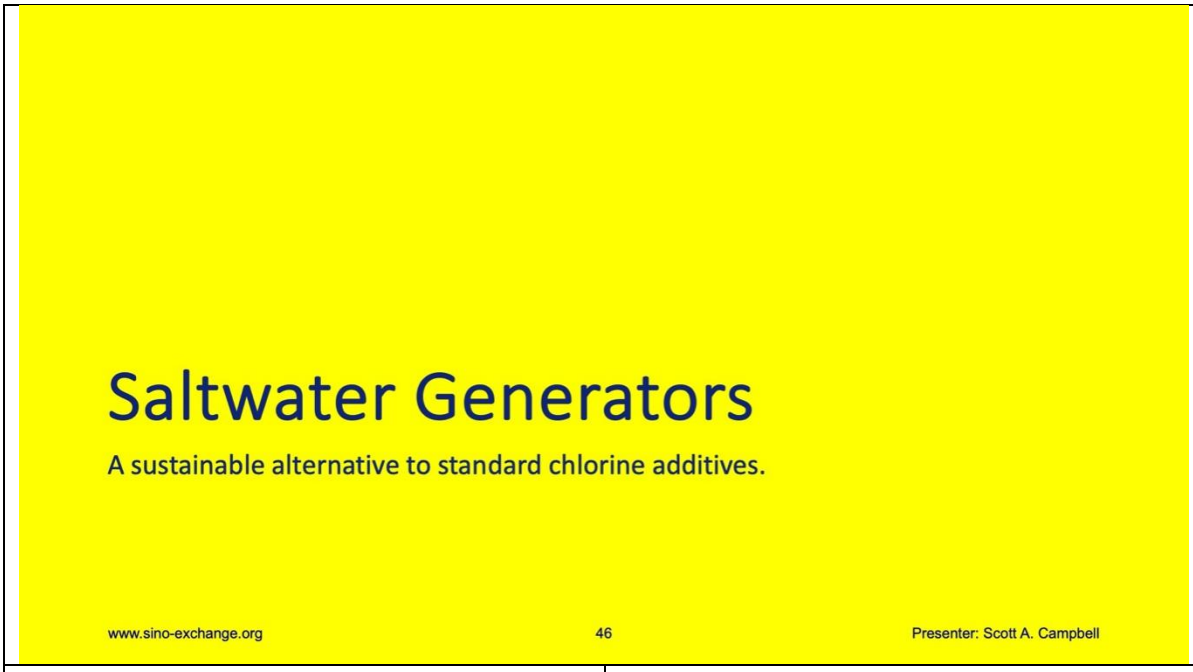
Now cautionary tales aside, the next thing that students would need to do is analyze their results and make the necessary calculations. This is great time for students to apply the study of ***3-dimenensional geometry*** or use any of these formulas to quickly estimate the volume of the pool.

Alternatively depending on your student's grade level students could also use a ***summation formula*** like what I have shown here from this textbook example. Then with the volume of the pool determine students would then be able to review the instructions for each chemical and determine the correct amount for each chemical that will be needed to correct for any imbalances in the pool water.

现在抛开警示故事不谈，学生们接下来需要做的就是分析他们的结果并进行必要的计算。这是学生应用三维几何研究或使用这些公式中的任何一个来快速估计水池体积的好时机。

或者，根据学生的年级水平，学生也可以使用一个求和公式，就像我在这里展示的这个教科书例子一样。然后，根据池水的体积确定学生将能够复习每种化学物质的说明，并确定纠正池水不平衡所需的每种化学物的正确量。



Finally, one of my favorite inventions in the pool industry is the Saltwater generator! ***First invented in 1972 by Cascade Pools in New Zealand.*** These little devices can turn standard table salt into a usable form of chlorine and back again. Making this a sustainable, and environmentally friendly solution to pool chemistry.

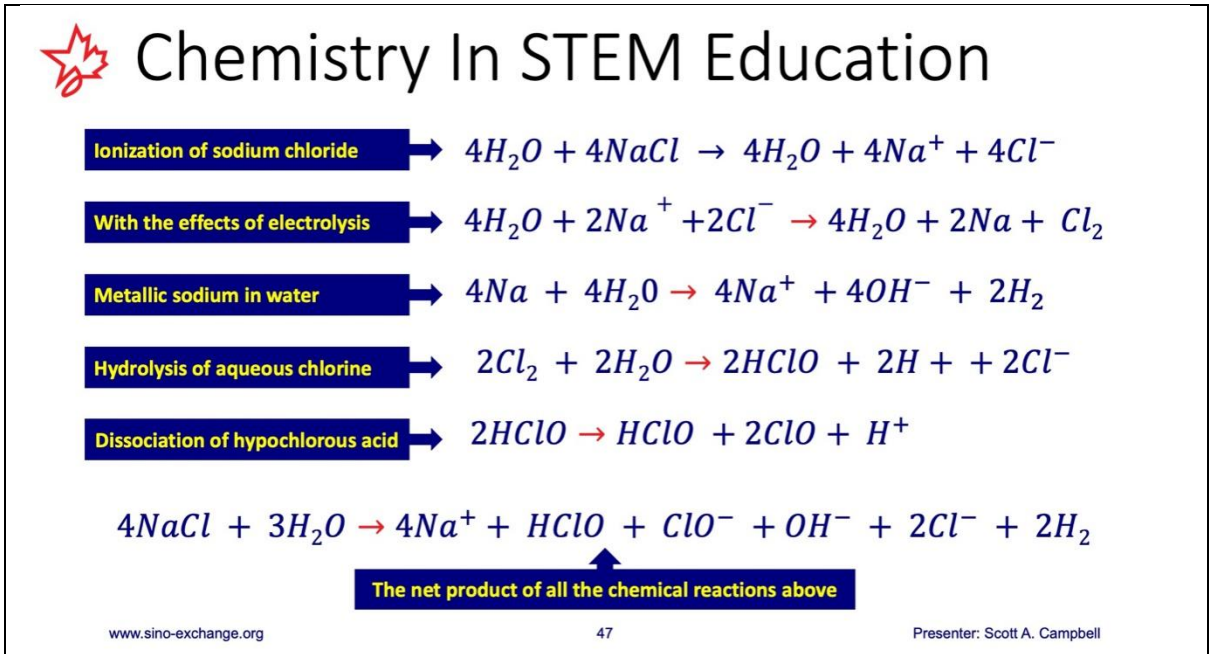
Now while this method of pool sanitization is not common in North America, countries like Australia which are relatively isolated from their trading partners tend to use salt-water generators almost exclusively.

Environmental and economic factors aside, the required salt levels needed for the effective generation of chlorine is equal to 3,000ppm which makes the chemical composition of the pool water almost undesignable from "***saline***". As a result, the natural chemistry of the pool water is ideally matched to our human physiology.

最后，我在泳池行业最喜欢的发明之一是盐水发生器！1972 年由新西兰的 Cascade Pools 首次发明。这些小装置可以将标准食盐转化为可用的氯，然后再返回。使其成为水池化学的可持续、环保的解决方案。

现在，虽然这种水池消毒方法在北美并不常见，但像澳大利亚这样与贸易伙伴相对隔离的国家往往几乎完全使用盐水发生器。

撇开环境和经济因素不谈，有效产生氯所需的盐含量等于 3000ppm，这使得池水的化学成分几乎不属于"盐水"。因此，池水的自然化学成分与我们人类的生理机能非常匹配。



Now you might thing that the chemical reaction that happens in a salt-water pool is relatively straight forward.
Salt is converted into chlorine and then back to salt again. Think again! The actual process that is happening is quite complex!

So, let's breakdown what's happening.

$$4NaCL \rightarrow 4Na^+ + 4Cl^-$$

First salt is dissolved in water which causes the molecules to ionize.

$$4Na^+ + 4Cl^- \rightarrow 4Na + 2Cl_2$$

Next, using a process of electrolysis, the charges of the sodium and chlorine ions are stripped. This will result in the formation of ***metallic sodium and chlorine gas*** inside the generating chamber. This process is accomplished using a 12v eclectic charge and a series of polarized platinum blades. Now the use of platinum makes these generators incredibly expensive to buy, but it's the only metal that can withstand the corrosive nature of the chemical reaction.

$$4Na + 4H_20 \rightarrow 4Na^+ + 4OH^- + 2H_2$$

Then the ***metallic sodium*** will instantly

现在你可能会认为，在盐水池中发生的化学反应是相对直接的。
盐被转化为氯，然后又重新变成盐。再想想！正在发生的实际过程相当复杂！

所以，让我们来分析一下正在发生的事情。

$$4NaCL \rightarrow 4Na^+ + 4Cl^-$$

首先将盐溶解在水中，使分子电离。

$$4Na^+ + 4Cl^- \rightarrow 4Na + 2Cl_2$$

接下来，使用电解过程，钠离子和氯离子的电荷被剥离。这将导致在发电室内形成金属钠和氯气。这一过程是使用 12v 折衷电荷和一系列极化铂片完成的。现在，铂的使用使这些发电机的购买成本高得令人难以置信，但它是唯一能够承受化学反应腐蚀性的金属。

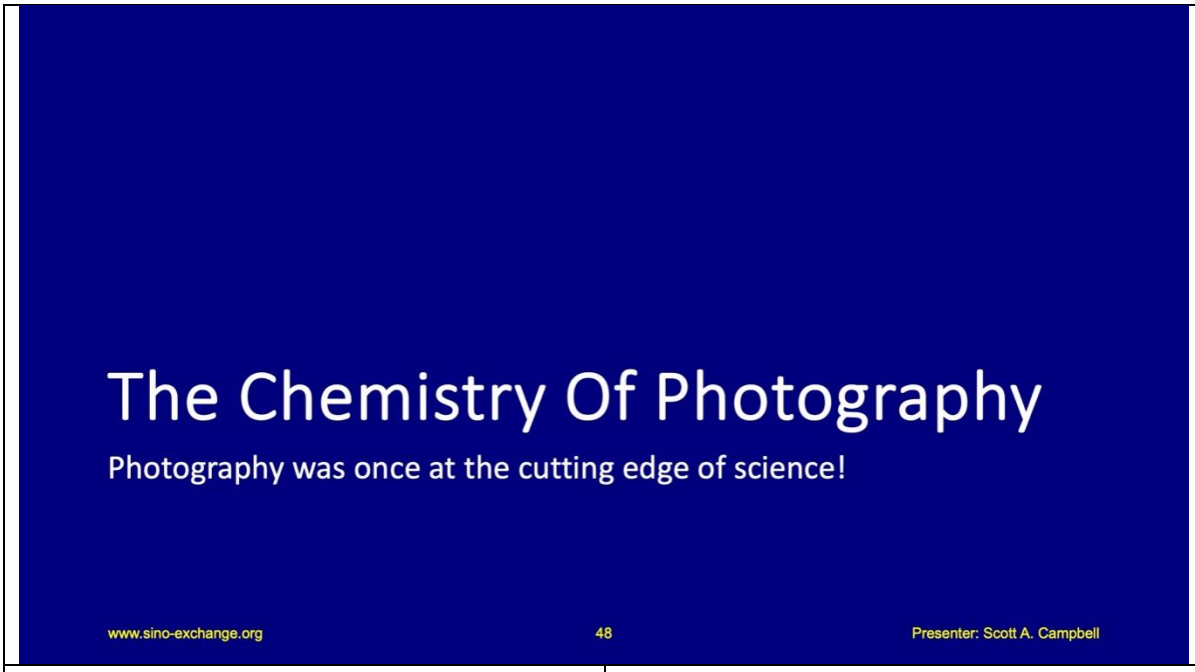
$$4Na + 4H_20 \rightarrow 4Na^+ + 4OH^- + 2H_2$$

然后金属钠会立即与水反应，生成氢氧化物和氢气。

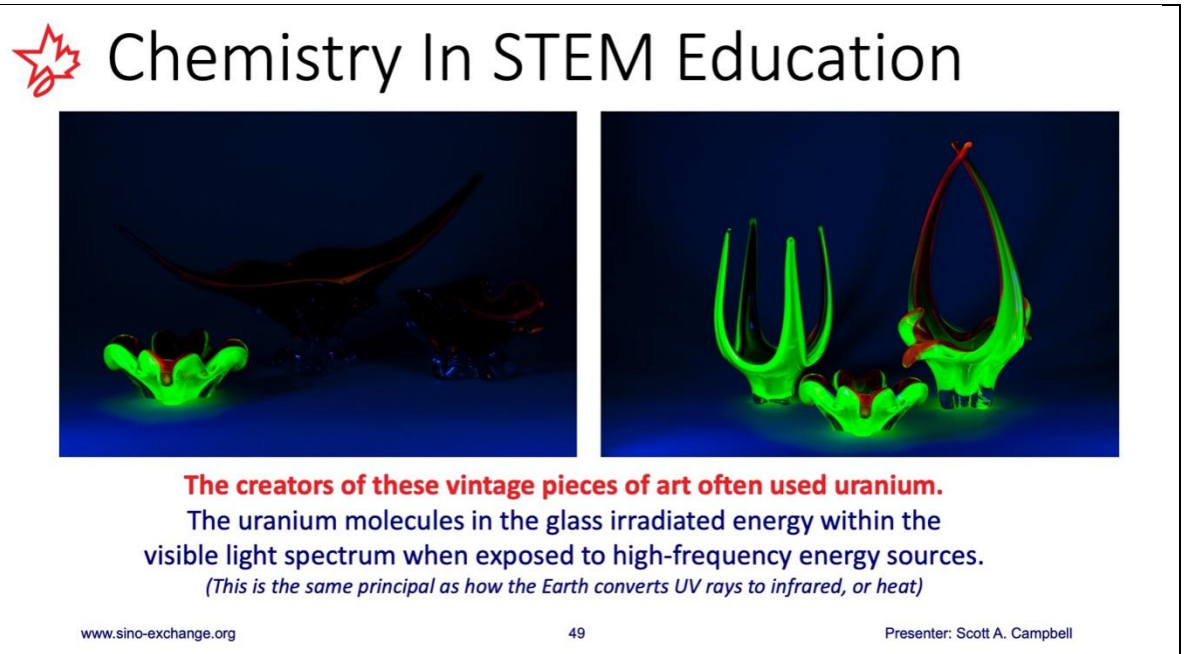
$$2Cl_2 + 2H_2O \rightarrow 2HClO + 2H^+ + 2Cl^-$$

react with water to create ***hydroxide*** and ***hydrogen gas***. $$2Cl2 + 2H_2O \rightarrow 2HClO + 2H^+ + 2Cl^-$$ And the second reaction that will happen will be the ***hydrolysis of aqueous chlorine gas*** which will result in the formation of ***hypochlorous acid***. $$2HClO \rightarrow HClO + ClO^- + H^+$$ This will immediately be followed by the dissociation of ***hypochlorous acid*** which will result in the formation of ***hypochlorite and hydrogen gas***. $$4NaCl + 3H_2O \rightarrow 4Na^+ + HClO + ClO^- + OH^- + 2Cl^- + 2H_2$$ This all happens in a mere instance, and this is what net chemical equation for all these reactions will look like. Now you are probably saying, wow! That's complex, but this is only the first half of what's happening. This reaction will then result in the formation of ***sodium hypochlorite (NaClO)***, which will eventually breakdown to create salt, a small amount of hydrogen off-gassing, and a small buildup of hydroxide over time. As such the ***entire reaction will also cause the pH of the pool to rise slowly.*** however, the natural tendency of a pool is for the pH to drop over time as a result of sweat and rainwater which are both acidic. Therefore, the natural by-product of this chemical reaction actually helps to offset undesirable trends in the pool natural chemistry. However, if natural causes do not keep the pH in check the use of ***hydrochloric acid*** can be used to help regulate the pH. **So, as you can see, something that seems simple enough actually requires an-depth study of molecular chemistry.** And that's	将发生的第二个反应将是氯气水溶液的水解，这将导致次氯酸的形成。 $$2HClO \rightarrow HClO + ClO^- + H^+$$ 紧接着是次氯酸的离解，这将导致次氯酸和氢气的形成。 $$4NaCl + 3H_2O \rightarrow 4Na^+ + HClO + ClO^- + OH^- + 2Cl^- + 2H_2$$ 这一切都发生在一个简单的例子中，这就是所有这些反应的净化学方程式。现在你可能在说，哇！这很复杂，但这只是事情的前半部分。然后，该反应将导致次氯酸钠（NaClO）的形成，次氯酸钠最终会分解生成盐，少量氢气排出，随着时间的推移，氢氧化物会少量积聚。 因此，整个反应也将导致池的 pH 缓慢上升。然而，水池的自然趋势是，由于汗液和雨水都是酸性的，pH 值会随着时间的推移而下降。因此，这种化学反应的天然副产物实际上有助于抵消水池自然化学的不良趋势。然而，如果自然原因不能控制 pH 值，可以使用盐酸来帮助调节 pH 值。 所以，正如你所看到的，看似简单的事情实际上需要对分子化学进行深入研究。这就是 STEM 的意义所在！学习严格的学术概念，同时在现实世界中应用科学、技术、工程和数学。

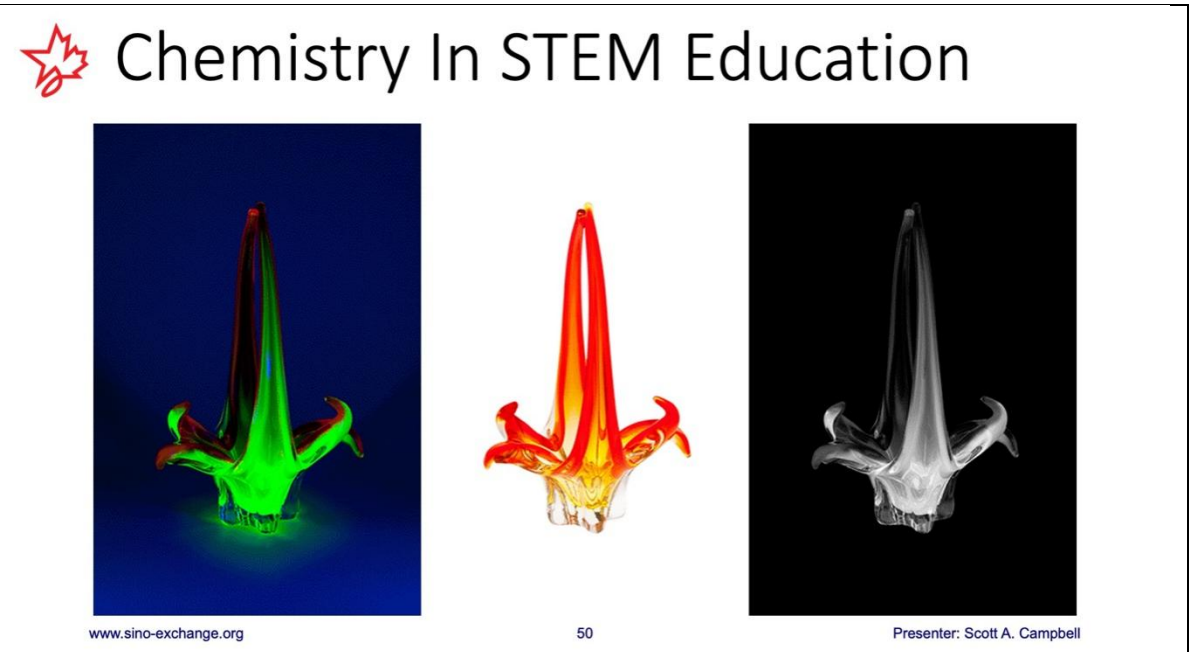
what STEM is all about! Learning rigours academic concepts while applying, science, technology, engineering, and math in real-world context.	



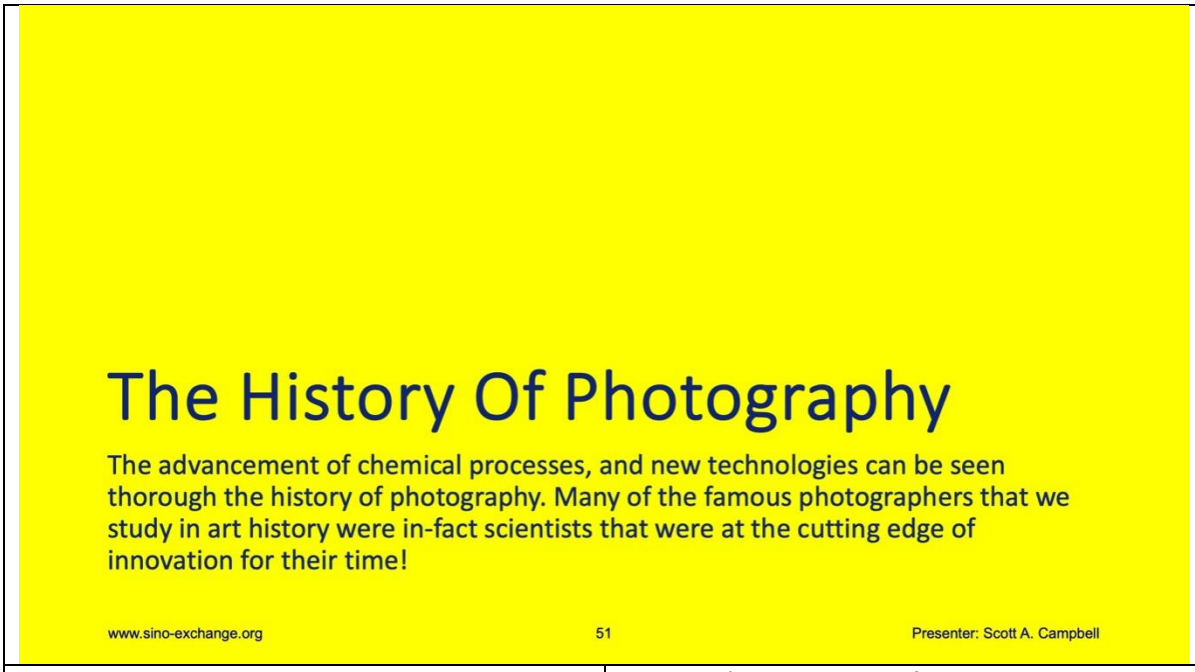
And that brings me to my next example. Photography! Now while most people just think that photography is a simplistic art form, history teaches us something completely different.	这就引出了我的下一个例子。照相术虽然大多数人只是认为摄影是一种简单的艺术形式，但历史教会了我们一些完全不同的东西。



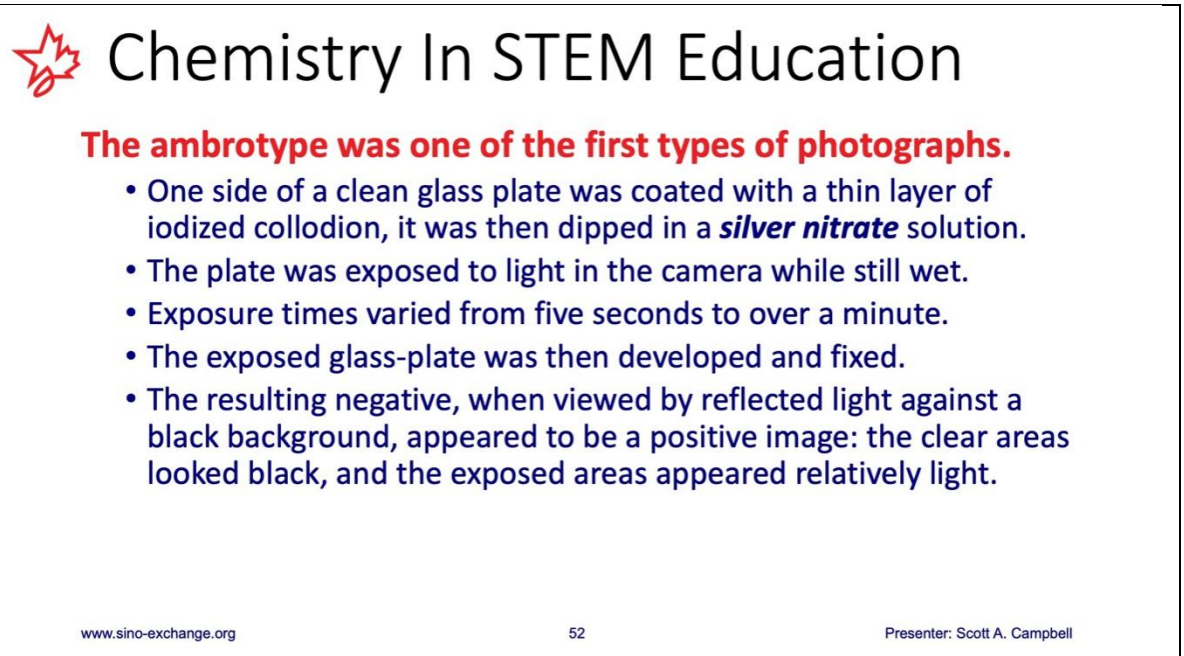
So, I want to start by sharing this example with you. It is the most unique request that I ever received while operating my company. It was to photograph an entire museum collection. however, this glass was unique as the artists was known for using uranium. Yes! you heard me right! Some of these works or art are enriched with uranium. Now you cannot see the effects of the uranium under normal light. However, if we apply high energy particles that are outside the visible light spectrum the uranium will absorb the energy and eradiate it as visible light. Much like the energy transfer process that happens with the Earth which converts UV rays from the sun to infrared radiation. So, this is what these artworks look like in the dark. Spectacular if you ask me. But one thing that you will notice is that we were unable to tell which one of these examples had uranium based on what we could see with the human eye alone.	因此，我想首先与大家分享这个例子。这是我在经营公司时收到的最独特的请求。这是为了拍摄博物馆的全部藏品。然而，这种玻璃是独一无二的，因为艺术家们以使用铀而闻名。 对你没听错！其中一些作品或艺术作品富含铀。现在你无法在正常光线下看到铀的影响。然而，如果我们应用可见光谱之外的高能粒子，铀将吸收能量并将其作为可见光进行辐射。就像地球上发生的能量转移过程一样，它将太阳的紫外线转化为红外辐射。 所以，这就是这些艺术品在黑暗中的样子。如果你问我的话，这真是太壮观了。但你会注意到的一件事是，我们无法根据肉眼所能看到的情况来判断这些例子中哪一个含有铀。



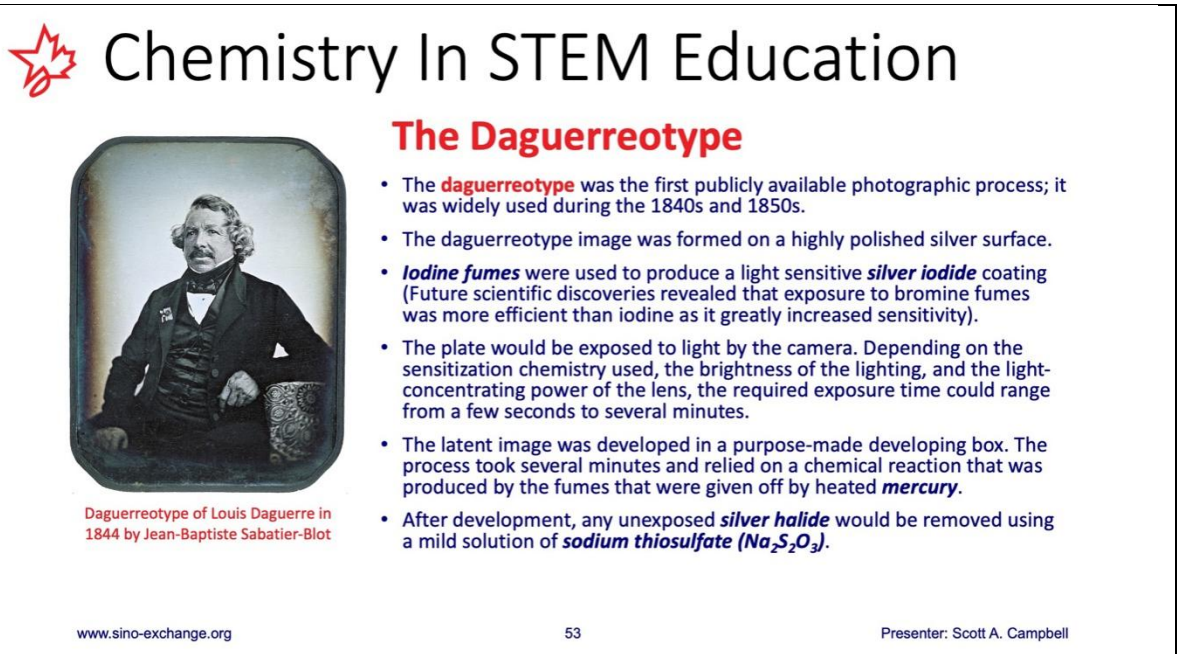
Therefore, the only way I could go about doing this project for the museum was to understand ***chemistry***, ***physics***, and the ***art of photography***.	因此，我为博物馆做这个项目的唯一方法就是了解化学、物理和摄影艺术。



So now that I have you interested, let's look at some of the chemical advancements that have been made as a result of photography over the years, because many of the famous photographers throughout history were in-fact scientists.	既然我有了你们的兴趣，让我们来看看这些年来由于摄影而取得的一些化学进步，因为历史上许多著名的摄影师实际上都是科学家。



The ambrotype was one of the first types of commercial photographs. With this method, photographers would take a simple glass plate and coat it with a thin layer of iodized collodion which was then dipped in a solution of silver nitrate. The plate would then be exposed to light inside the camera while it was still wet, and this was incredibly difficult to do. Moreover, the exposure times varied from five seconds to more than a minutes and this made photographing most objects even more difficult. The glass-plate would then be developed and fixed though a series of chemical processes. The result of this process created a negative image, which would then be viewed by reflecting light against a black background which would make the image appears as if it were positive image. This was because the clear areas would appear black, and the exposed areas would appear relatively light.	该模型是最早的商业照片类型之一。用这种方法，摄影师会拿一个简单的玻璃板，在上面涂上一层薄薄的碘化火棉胶，然后将其浸入硝酸银溶液中。然后，当板仍然潮湿时，将其暴露在相机内部的光下，而且，曝光时间从 5 秒到 1 分钟不等，这使得拍摄大多数物体变得更加困难。 然后，玻璃板将通过一系列化学工艺进行开发和固定。这个过程的结果产生了一个负图像，然后通过在黑色背景下反射光来观看，这将使图像看起来像是正图像。这是因为清晰的区域会看起来是黑色的，而暴露的区域会显得相对较轻。



Moving on to Louis Daguerre. The invention of the Daguerreotype advanced photography as this process had significantly better quality, was more durable than the glass ambrotype, and was easier to work with.

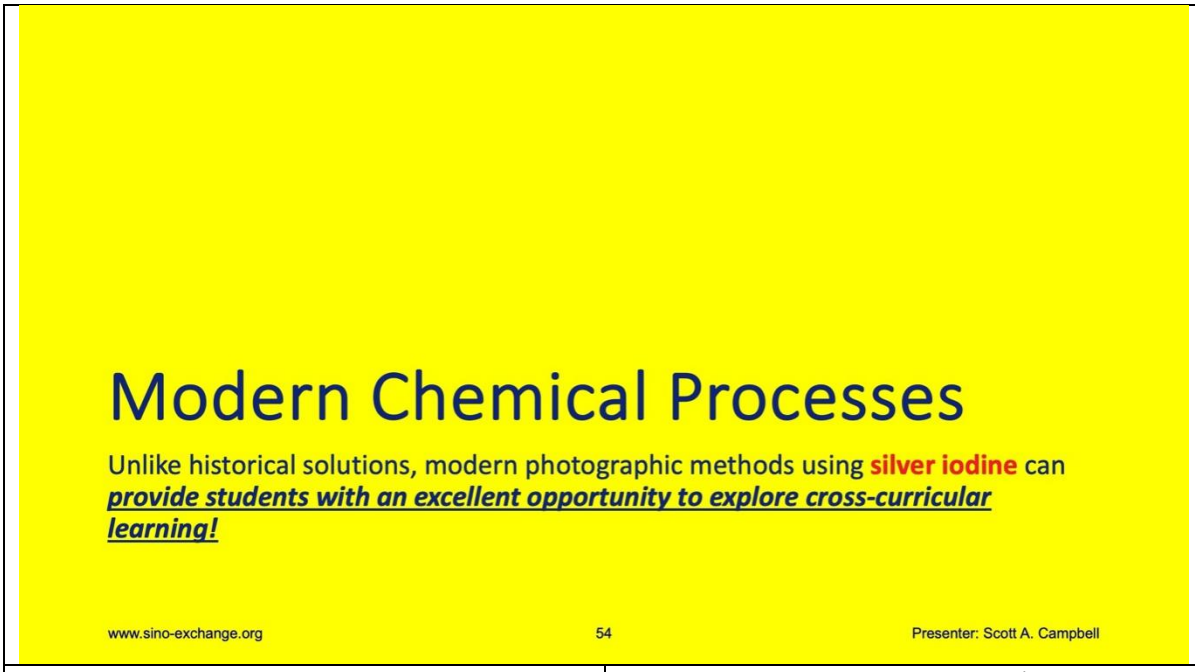
Now the daguerreotype would form an image on a polished silver surface. These highly polished silver plates were then made light sensitive using ***iodine fumes*** which would produce a light sensitive ***silver iodide coating***. This light sensitive silver plate would then be exposed to light inside the camera.

The latent image would then be developed in purpose-made developing box using ***mercury*** vapors. Then, after development, any unexposed silver halide would be removed using a mild solution of "***sodium thiosulfate***".

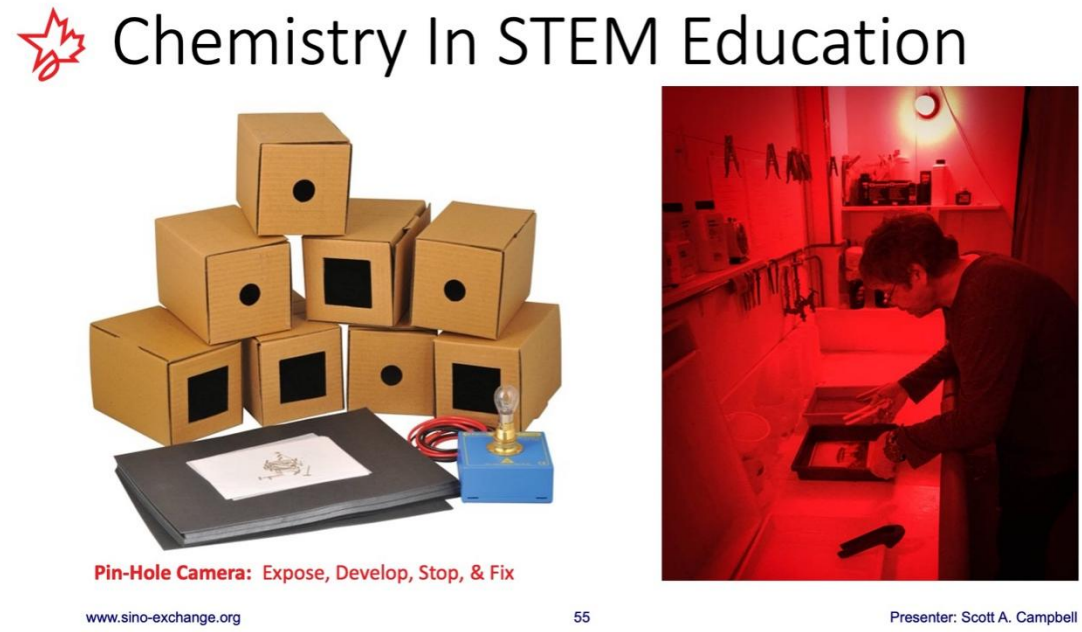
接下来是路易斯·达盖尔。Daguerreotype 高级摄影术的发明是因为该方法具有明显更好的质量、比玻璃橱柜更耐用，而且更容易操作。

现在，银版将在抛光的银表面上形成图像。这些高度抛光的银板然后使用碘烟制成光敏的，这将产生光敏的碘化银涂层。然后，这种感光银片将暴露在相机内部的光线下。

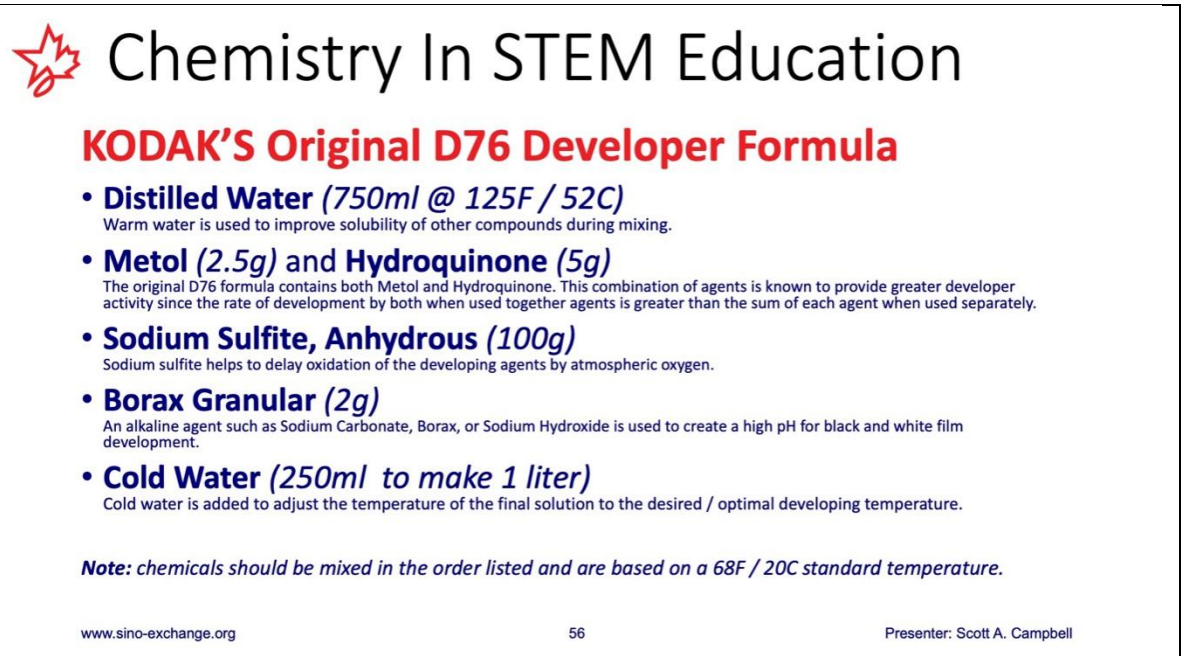
然后，潜像将在特制的显影盒中使用汞蒸汽进行显影。然后，显影后，使用温和的"硫代硫酸钠"溶液去除任何未暴露的卤化银。



While the ***ambrotype*** was difficult to handle and incredibly fragile, and the ***daguerreotype*** being incredibly toxic! It goes without saying that these methods would be unsuitable for students to learn in school. However, photographic methods that use ***silver iodine*** can provide students with excellent cross-circular learning opportunities.	而安版很难处理，而且非常脆弱，银版毒性非常大！不用说，这些方法不适合学生在学校学习。然而，使用银碘的摄影方法可以为学生提供极好的跨循环学习机会。



Even without fancy camera equipment, students can explore the scientific and artistic aspects of B&W photography using a pin hole camera. In this situation, photographic paper is placed in a box in complete darkness. A pin hole is then made on the opposite side of the box which is then covered with tape. The tape is carefully removed to start the exposure and is then replaced to stop the exposure. The print can then be developed in a darkroom, or even a bathroom sink providing that you do not expose the paper to any white light.	即使没有花哨的摄影设备，学生也可以使用针孔相机探索黑白摄影的科学和艺术方面。在这种情况下，相纸被放在一个完全黑暗的盒子里。然后在盒子的另一侧打一个针孔，然后用胶带盖住。小心地取下胶带以开始曝光，然后更换胶带以停止曝光。然后可以在暗室甚至浴室水槽中显影，前提是你不会将纸张暴露在任何白光下。



Now while Kodak's bankruptcy in 2012 was a big blow to the B&W community! It did not stop professional photographers and enthusiasts. This was because the legendary D76 solution can be made at home, or at school using some common household compounds.

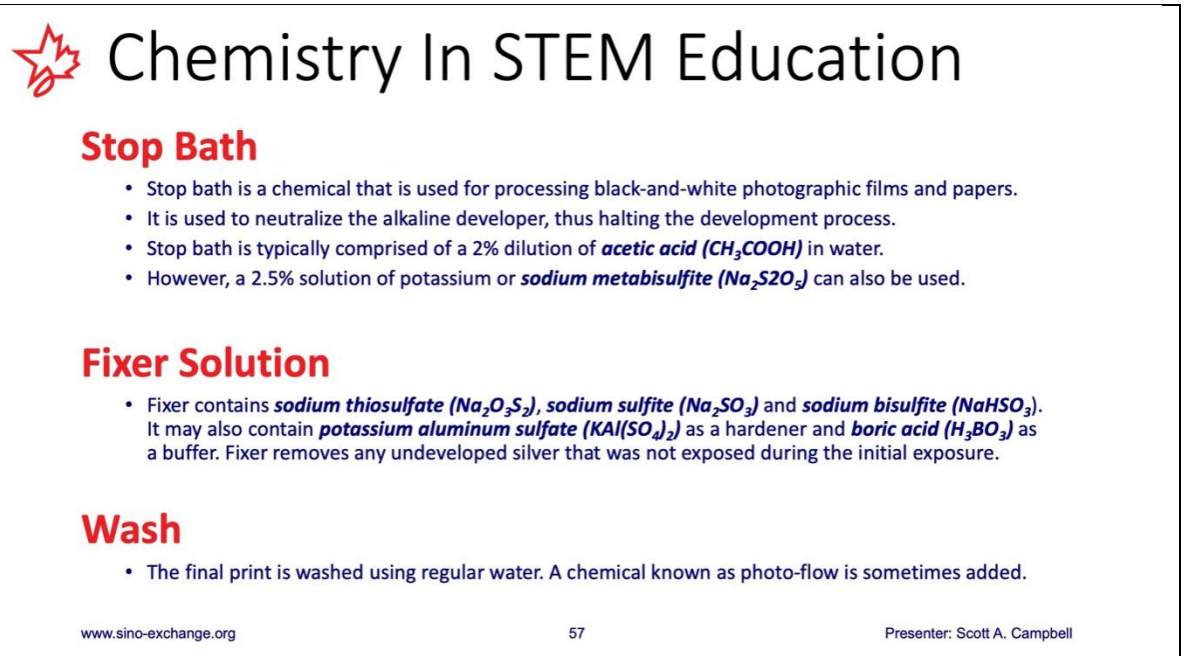
- First, start by using 750ml of distilled water at a temperature of 52°C
- Then add 2.5g of Metol $(C_7H_{10}NO)_2SO_4$ and 5g of Hydroquinone ($C_6H_6O_2$)
- Add 100g of sodium sulfite (Na_2SO_3) and Anhydrous (NH_3)
- And the last chemical that needs to be added is 2g of Borax Granular (Na_2H_4B)
- The final step is to add and attritional 250ml of cold water to bring the solution down to 20°C which is the optimal temperature for developing film.

Now if all that sounds too complicated, **don't worry! D76 is still made under the Kodak name by a 3rd party which has kept this product alive to this day.**

现在，柯达在 2012 年的破产对 B&W 社区来说是一个巨大的打击！它并没有阻止专业摄影师和爱好者。这是因为传说中的 D76 解决方案可以在家里或学校使用一些常见的家用化合物制作。

- 首先，在 52 摄氏度的温度下使用 750 毫升蒸馏水
- 然后加入 2.5g Metol（$C_7H_{10}NO$）$_2SO_4$ 和 5g 氢醌（$C_6H_6O_2$）
- 添加 100 克亚硫酸钠（Na_2SO_3) 和无水（NH_3）
- 最后需要添加的化学品是 2g 硼砂颗粒（Na_2H_4B）
- 最后一步是添加并消耗 250 毫升冷水，使溶液降至 20 摄氏度，这是显影薄膜的最佳温度。

现在，如果这一切听起来太复杂，不要担心！D76 仍然是由第三方以柯达的名义生产的，该第三方一直保持着该产品的生命力。



Now after the developing stage has been completed, the chemical reaction needs to be neutralized by a process known a chemical known as "***STOP bath***", "***fixed***", and then "***washed***".

So, the "***stop bath***" neutralizes the alkaline developer, thus halting the development process. Now "***stop bath***" is typically comprised of a diluted solution of ***acetic acid (CH_3COOH)***. Therefore, you can actually use household vinegar for this if you wanted to. However, a solution of ***potassium*** or ***sodium metabisulfite (Na_2S2O_5)*** can also be used as well.

Next, is the "**fixer solution**" which removes any unexposed silver. The "**fixer solution"** contains ***sodium thiosulfate ($Na_2O_3S_2$)***, ***sodium sulfite (Na_2SO_3)*** and ***sodium bisulfite ($NaHSO_3$)***.

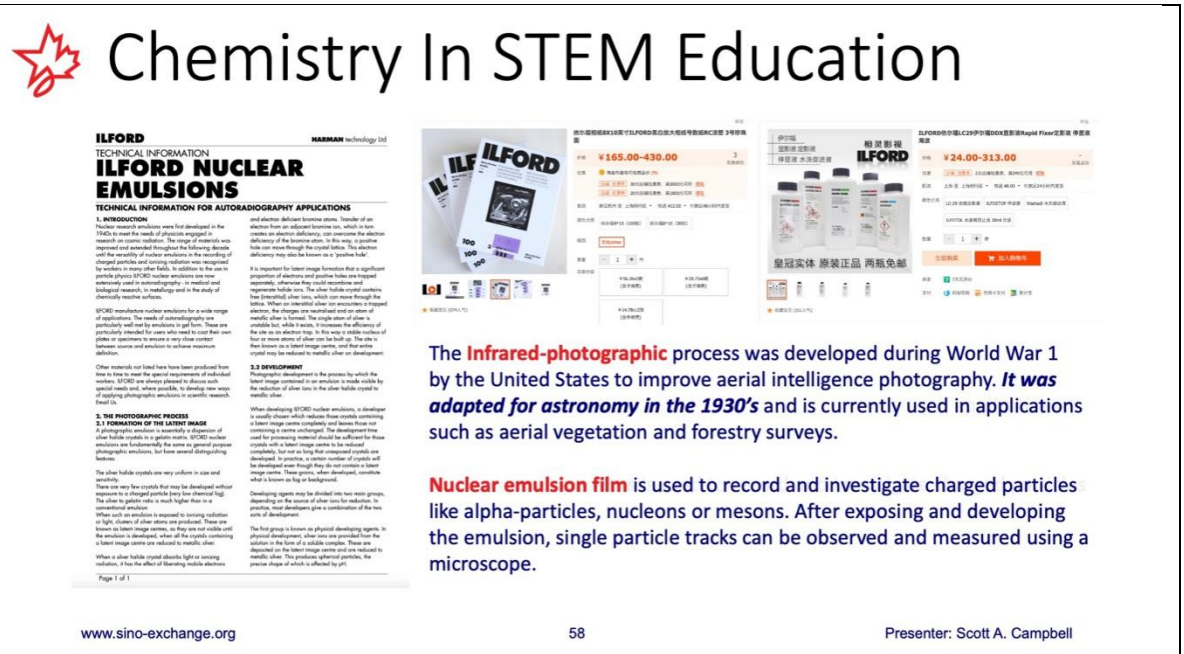
And finally, the wash! Now there is nothing special about this, but some photographers do like to use a product that is known as "***photo-flow***" to reduce the required wash time so they can conserve water.

现在，在显影阶段完成后，化学反应需要通过一种称为"停止浴"的化学物质进行中和，"固定"，然后"洗涤"。

因此，"停止浴"中和碱性显影剂，从而停止显影过程。现在，"停止浴"通常由稀释的乙酸溶液（CH_3COOH）组成。因此，如果你愿意，你实际上可以使用家用醋。然而，焦亚硫酸钾或焦亚硫酸钠（$Na_2S_2O_5$）溶液也可以使用。

接下来，是"定影液"，它可以去除任何未暴露的银。"定影液"含有硫代硫酸钠（$Na_2O_3S_2$）、亚硫酸钠（Na_2SO_3）和亚硫酸氢钠（$NaHSO_3$）。

最后，清洗！现在这并没有什么特别的，但一些摄影师确实喜欢使用一种被称为"照片流"的产品来减少所需的洗涤时间，这样他们就可以节约用水。

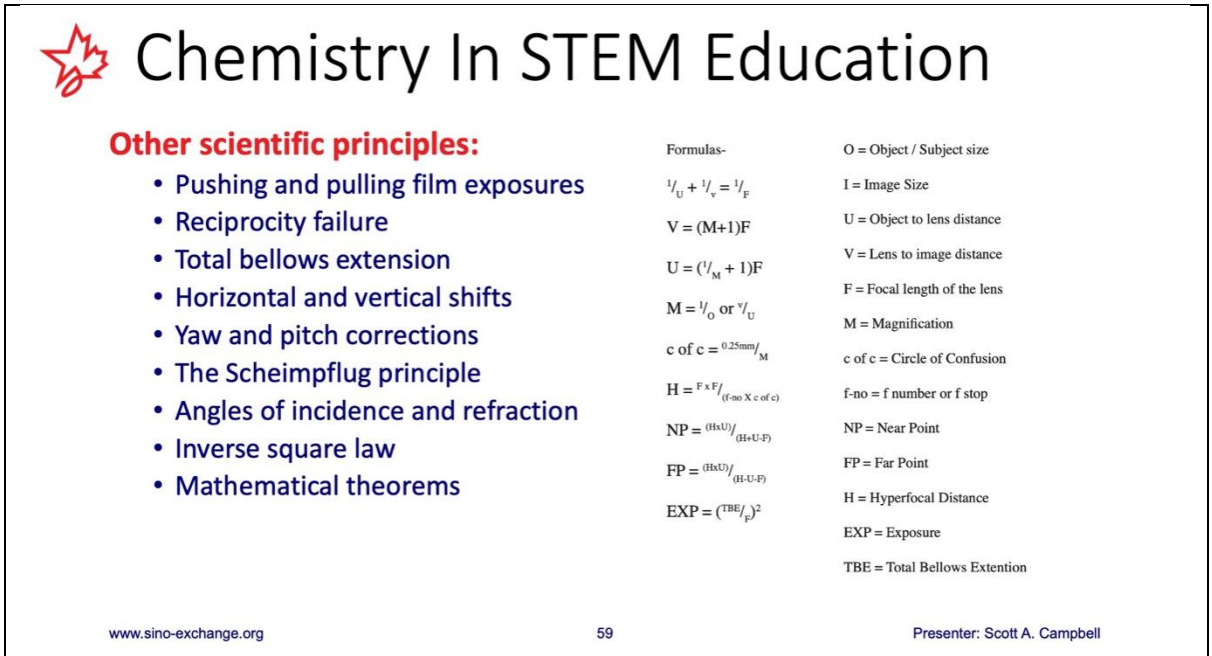


Now as I mentioned before, you can still buy B&W chemicals. Not only that, but there's also been a reassurance of new products coming to the market in recent years. This is because there are some advanced photographic processes that can only be done using chemical-based photographic solutions, and this makes film the go to solution for several specialty niches.

For instance, 2 specialized products that I have used in the past are "**Ilford nuclear emulsion"** and **"infrared films"**. I am also particularly fond of **Fuji Across film** in combination with the **Ilford fine grain developer** for ultra-high-resolution imaging. Now if you are interested in some of the scientific applications of these specialty products: Infrared film is great for ***astronomy,*** and ***vegetation studies***, but it can also be used for ***military recognisance***. On the other hand, **nuclear emulsion films** are great for investigating charged particles and can also be used to find structural faults in things like bridges and airplane fuselages due to material fatigue during a safety audit.

正如我之前提到的，你仍然可以买到 B&W 化学品。不仅如此，近年来新产品上市也让人放心。这是因为有一些先进的摄影工艺只能使用基于化学的摄影解决方案来完成，这使得胶片成为几个专业领域的首选解决方案。

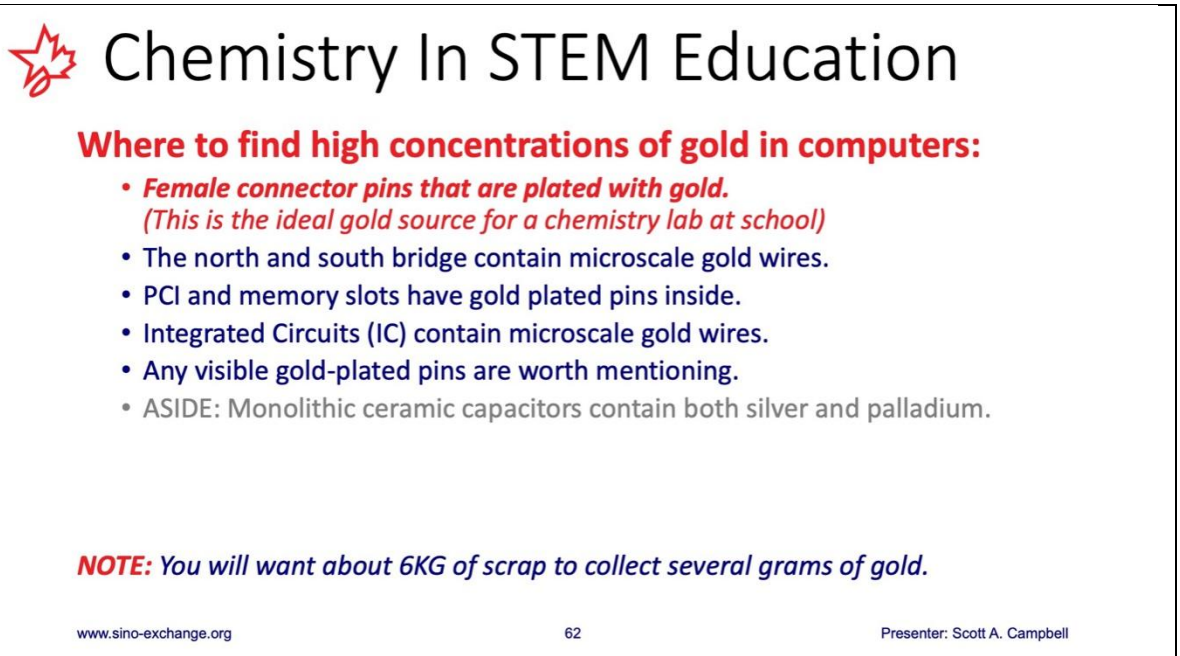
例如，我过去使用过的两种专业产品是"伊尔福德核乳液"和"红外膜"。我还特别喜欢 Fuji Across 胶片与 Ilford 细粒度显影剂相结合，用于超高分辨率成像。现在，如果你对这些专业产品的一些科学应用感兴趣：红外胶片非常适合天文学和植被研究，但它也可以用于军事识别。另一方面，核乳胶膜非常适合研究带电粒子，也可用于在安全审计期间发现桥梁和飞机机身等因材料疲劳而导致的结构故障。



So, as you can see there is a lot of science in photography, and I haven't even gotten into principles such as: Pushing and pulling film, reciprocity, the Scheimpflug principle, or any of these other mathematical theorems. And these are all things that students need to learn when studying advanced photographic concepts at the university level.	所以，正如你所看到的，摄影中有很多科学，我甚至还没有进入原理，比如：推拉胶片，互易性，Scheimpflug 原理，或者任何其他数学定理。这些都是学生在大学学习高级摄影概念时需要学习的东西。

And finally, we will explore chemical processes to recover precious metals and how we can adapt these methods to make them more appropriate for high-school students. Furthermore, the idea of "***precious metal recovery***" also ties in well with the humanities as we explore the social, economic, and environmental aspects of our decisions, and this is something that the World Economic Forum has called for with reforms to STEM education.	最后，我们将探索回收贵金属的化学过程，以及如何调整这些方法，使其更适合高中生。此外，在我们探索决策的社会、经济和环境方面时，"贵金属回收"的理念也与人文学科密切相关，这也是世界经济论坛在 STEM 教育改革中呼吁的。

Now regrettably, most e-waste is not recycled, but as you will see in a moment the recycling process is not overly environmentally friendly either. So, by exploring precious metal recovery methods we have an opportunity to explore the philosophical and ethical issues that relate the consequences of our actions or inactions. However, one company could change the way we look at e-waste is Mint Innovation from New Zealand. Again, this is the same country that invented the saltwater generator as an environmentally sustainable solution to pool water sanitization. Now Mint innovation has developed a revolutionary new method of ***recovering precious metals*** such as ***copper***, ***tin***, ***gold***, and ***palladium*** using ***microbes***. While this process is not something that we can explore in a high-school setting, it is a great case study share with the students either before or after learning how traditional chemical processes work.	现在令人遗憾的是，大多数电子垃圾都没有被回收，但正如你稍后将看到的那样，回收过程也不太环保。 因此，通过探索贵金属回收方法，我们有机会探索与我们的作为或不作为的后果相关的哲学和伦理问题。然而，有一家公司可能会改变我们看待电子垃圾的方式，那就是新西兰的 Mint Innovation。同样，正是这个国家发明了盐水发生器，作为池水消毒的环境可持续解决方案。 现在，铸币局的创新开发了一种利用微生物回收铜、锡、金和钯等贵金属的革命性新方法。虽然这个过程不是我们可以在高中环境中探索的，但它是在学习传统化学过程如何工作之前或之后与学生分享的一个很好的案例研究。



Now if you want to do an e-waste lab the first thing that you will want to do is to collect scraps that contain precious metals, and circuit boards from older computers due tend to be better for this kind of experiment. But what type of components have the highest concentrations of gold?

Well, the best sources of gold can be found in:

- Female connector pins that are plated with gold
- The north and south bridge contain microscale gold wires
- PCI and Memory slots have gold plated pins
- Integrated circuit (IC) contain gold wires
- And any visible gold-plated pins are worth mentioning.
- And while it won't be relevant to this experiment, Monolithic ceramic capacitors are great sources of other types of precious metals such as silver and palladium.

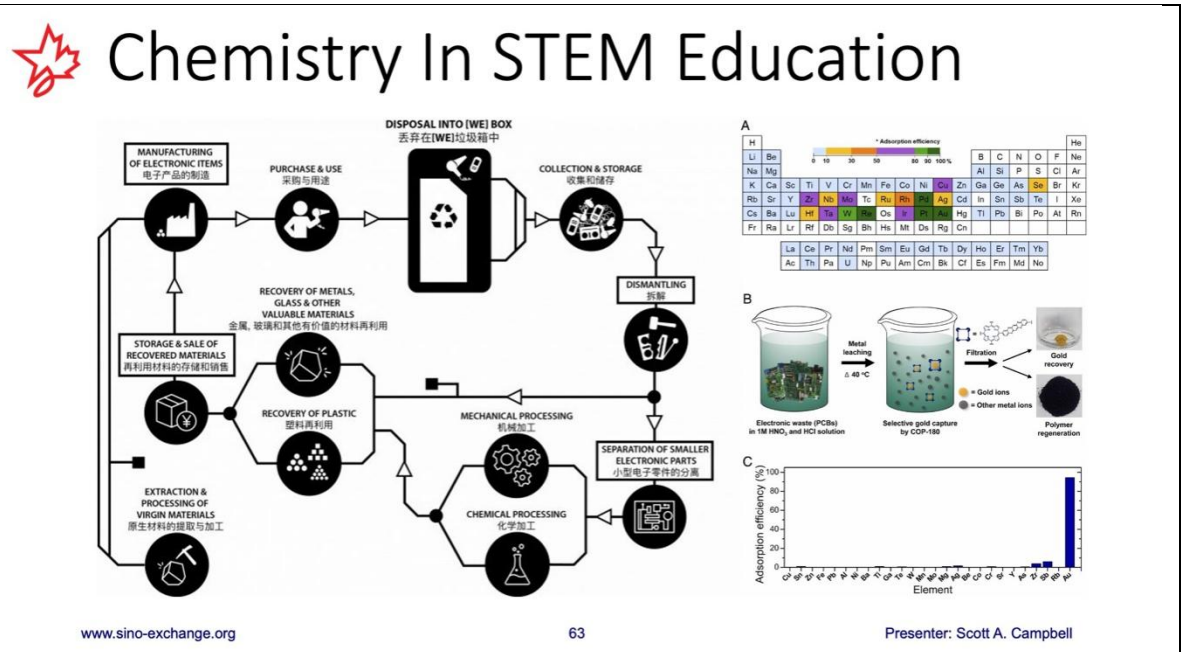
Please note that you will want about 6KG of scrape to collect enough gold for this type of lab experiment.

现在，如果你想做一个电子垃圾实验室，你首先要做的就是收集含有贵金属的废料，而旧电脑的电路板往往更适合这种实验。但哪种成分的金浓度最高？

好吧，黄金的最佳来源可以在以下地方找到：

- 镀金母连接器引脚
- 包含微型金线的南北桥
- PCI 和内存插槽具有镀金引脚
- 集成电路（IC）包含金线
- 任何可见的镀金引脚都值得一提。
- 虽然这与本实验无关，但单片陶瓷电容器是银和钯等其他类型贵金属的重要来源。

请注意，您将需要大约 6 公斤的刮削物来收集足够的黄金用于这种类型的实验室实验。



While mimicking commercial e-waste recovery methods would be ideal, the physical limitations of a classroom learning environment are somewhat prohibitive due to a lack of time, space, and resources. However, we can draw inspiration from these commercial practices and then simplify them. So, let's start by analyzing some of the differences.

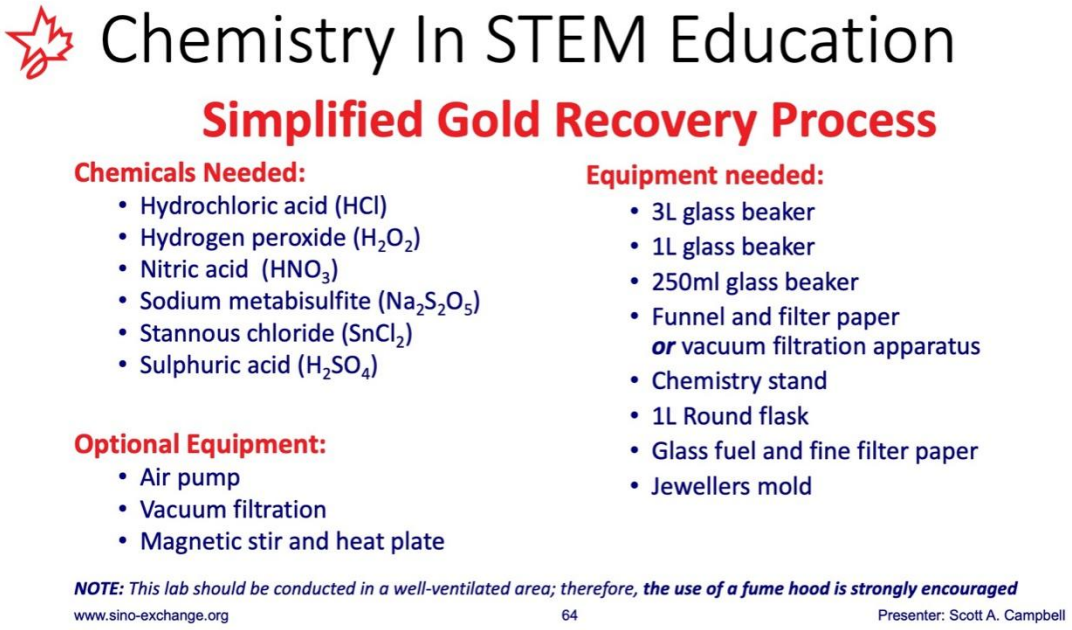
Frist, official recycling processes require a large number of exotic chemical compounds. These compounds allow the chemical process to completely dissolve the entire structure of the material be recycled. As a result, the superiority of this process will allow for all the precious metals to be recovered. For instance, once the entire circuit board has been dissolved in acid, different chemical compounds can be used to precipitate each metal out of the solution in a specific order (based on its electron affinity and reactivity level of precious metal to be recovered). These metals will include ***copper***, ***lead***, ***iron***, and the more precocious metals such as: ***silver***, ***gold***, and ***palladium***. Once each metal has been precipitated out of the solution it will then need to be refined before smelting.

虽然模仿商业电子废物回收方法将是理想的，由于缺乏时间、空间和资源，课堂学习环境的物理限制有些令人望而却步。然而，我们可以从这些商业实践中获得灵感，然后将其简化。所以，让我们从分析其中的一些差异开始。

首先，官方的回收过程需要大量的外来化合物。这些化合物允许化学过程完全溶解被回收材料的整个结构。因此，这种工艺的优越性将允许回收所有的贵金属。例如，一旦整个电路板都溶解在酸中，就可以使用不同的化合物以特定的顺序（基于其电子亲和力和待回收贵金属的反应性水平）将每种金属从溶液中沉淀出来。这些金属将包括铜、铅、铁和更早熟的金属，如：银、金和钯。一旦每种金属从溶液中沉淀出来，就需要在熔炼前进行精炼。

虽然这个过程太复杂了，无法在学校里探索，但一个只回收暴露的黄金的简化过程可以为学生提供真实的学习体验，这种类型的电子垃圾实验室在小学有"断路器空间"的学校也很有效，因为这些活动往往会导致电子垃圾的积累，然后供高中学生使用。

While this process is too complex to explore in school, a simplified process that only recovers the exposed gold can provide students with an authentic leaning experience, and this type of e-waste lab also works well in schools that have a "***breaker space"*** in the primary division as these activities tend to result in an accumulation of e-waste which can then be used by students in the senior school.	



Now to get started with an e-waste lab you will need the chemicals and equipment listed here on this slide. You will need the following chemical compounds:

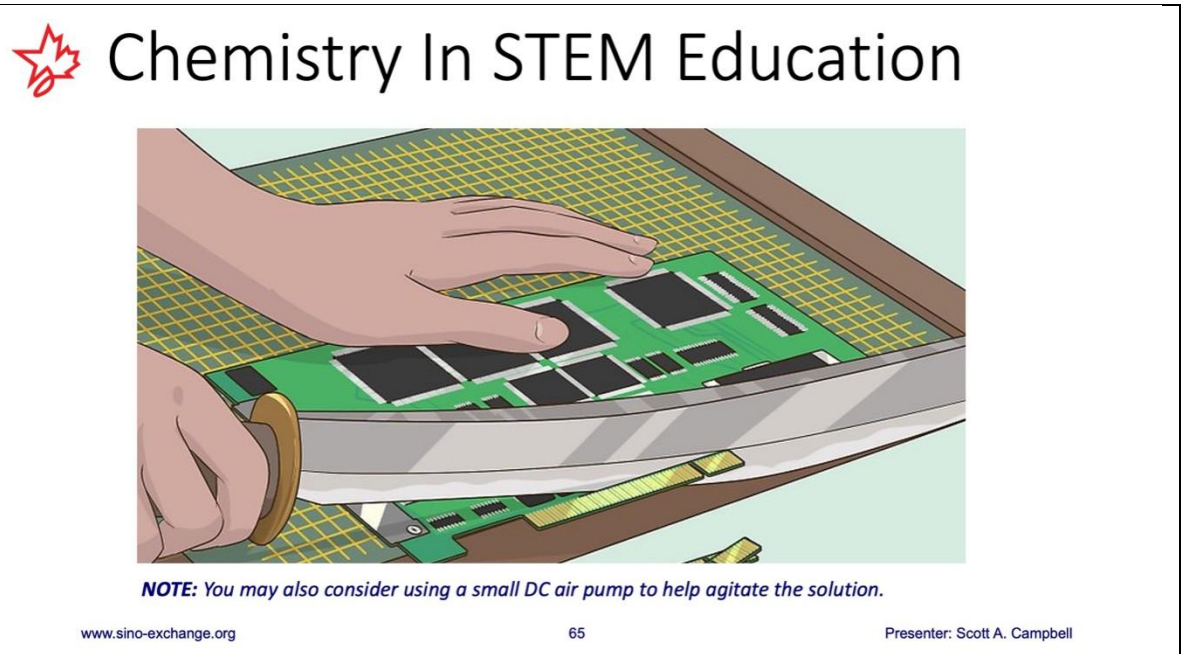
- ***Hydrochloric Acid (HCl)***
- ***Hydrogen peroxide (H_2O_2)***
- ***Nitric Acid (HNO_3)***
- ***Sodium metabisulfite ($Na_2S_2O_5$)***
- ***Stannous chloride ($SnCl_2$)***
- ***Sulfuric acid (H_2SO_4)***

Furthermore, you will also need a number of standardized lab items. And finally, there are a few things that you may want to use which will make the recovery process even easier! These items include a small DC air pump which can be used to help agitate the solution, vacuum filtration to improve the filtration process, and a magnetic stir-plate to make it easier to mix the various solutions that you will use during the lab.

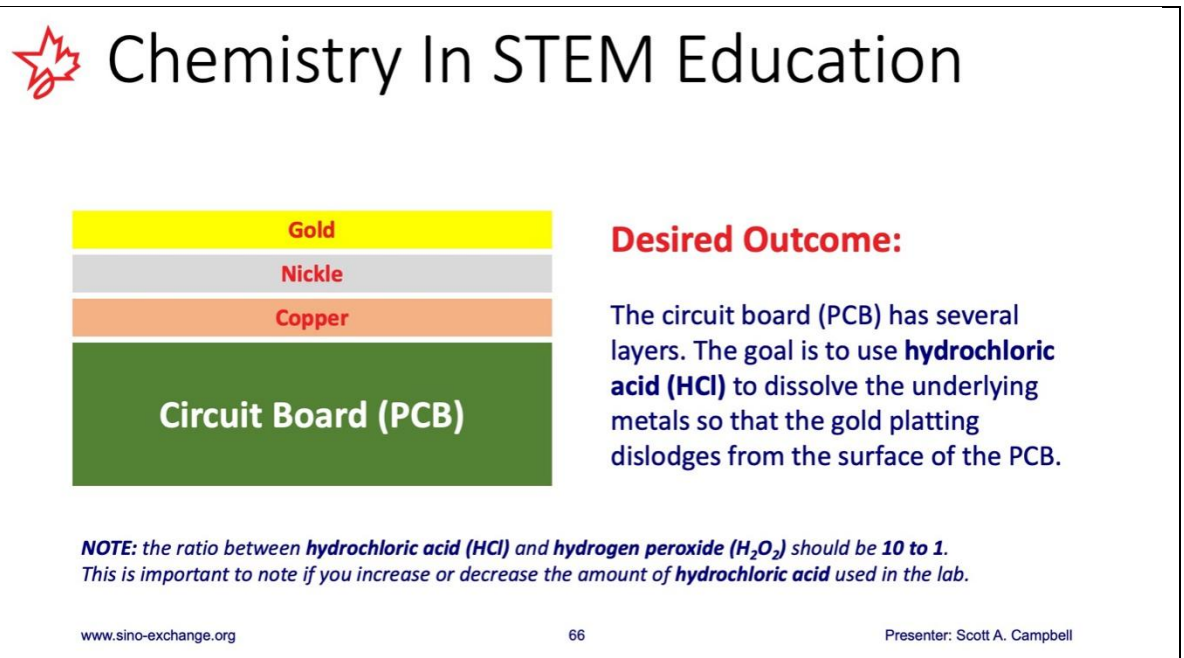
现在，要开始使用电子垃圾实验室，您需要本幻灯片中列出的化学品和设备。您将需要以下化合物：

- 盐酸（HCl）
- 过氧化氢（H_2O_2）
- 硝酸（HNO_3）
- 偏亚硫酸氢钠（$Na_2S_2O_5$）
- 氯化亚锡（$SnCl_2$）
- 硫酸（H2SO_4）

此外，您还需要一些标准化的实验室项目。最后，你可能想使用一些东西，这将使恢复过程更加容易！这些物品包括一个小型直流气泵，可以用来帮助搅拌溶液，真空过滤可以改善过滤过程，还有一个磁性搅拌板，可以更容易地混合实验室中使用的各种溶液。

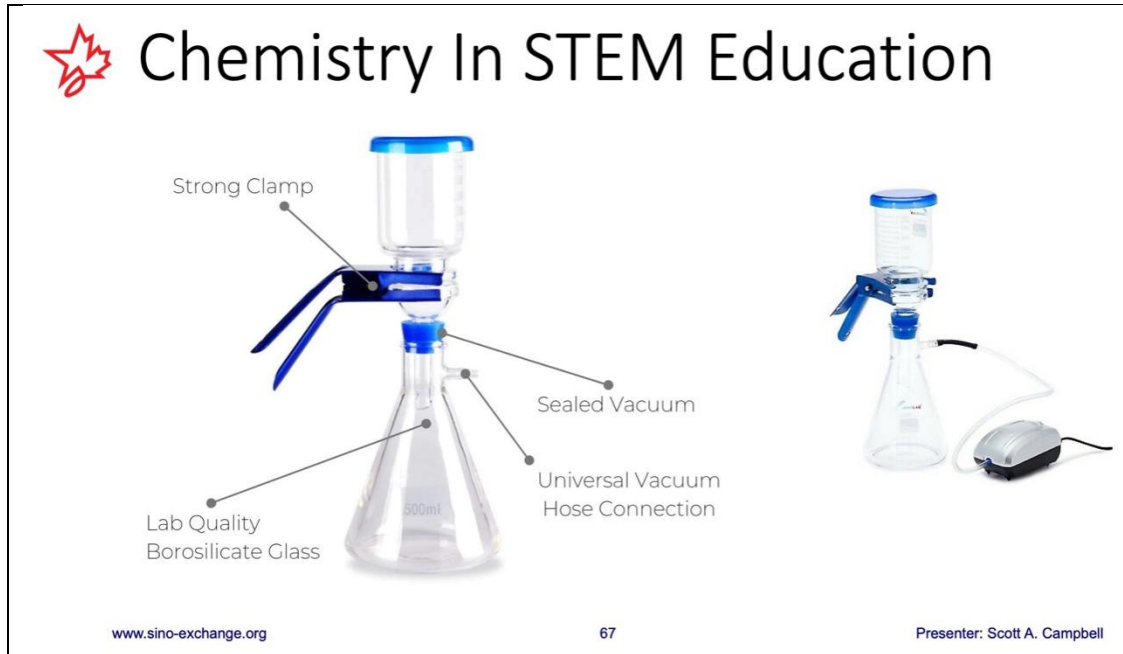


Now this process is only capable of recovering the exposed gold that is found on the connecting fingers of a circuit board. Therefore, it is best to use a paper guillotine or tinsnips to cut the fingers off and send the remaining circuit board off to a commercial recycling facility. Then place the scraps in a large 3L glass beaker before adding 1L of ***hydrochloric acid (HCl)***. The clear ***hydrochloric acid*** will start turning green as it reacts with the various metals from the circuit board.	现在，这个过程只能回收电路板连接指上暴露的黄金。因此，最好用切纸机或锡剪把手指切掉，然后把剩下的电路板送到商业回收设施。然后在加入 1L 盐酸（HCl）之前，将碎屑放入 3L 的大玻璃烧杯中。当清澈的盐酸与电路板上的各种金属反应时，它会开始变绿。



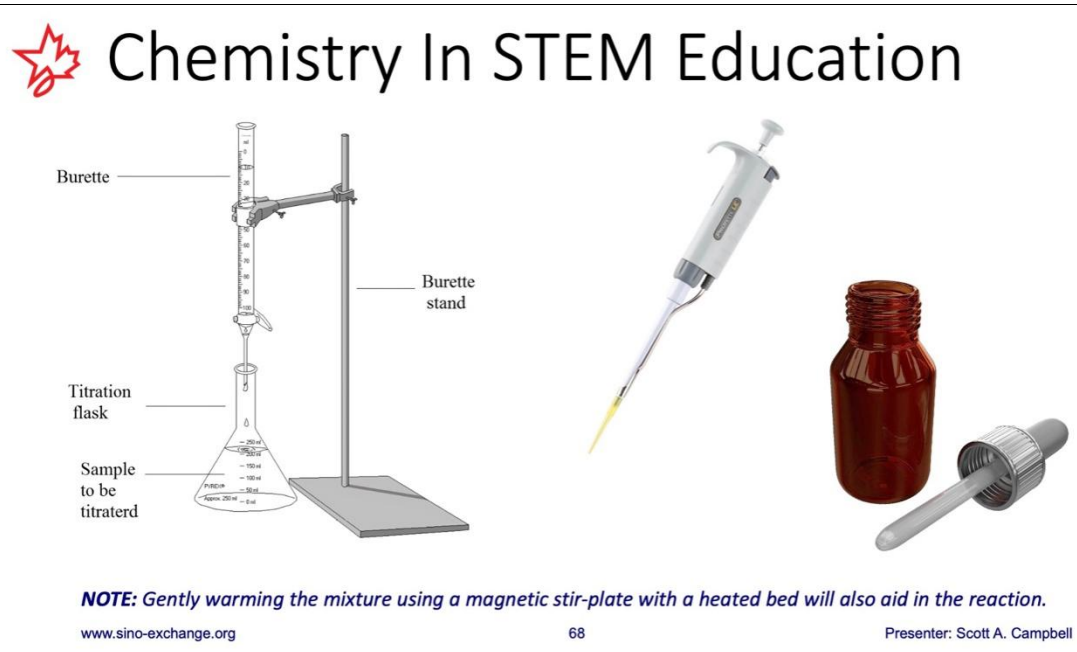
Now gold connectors on a ***Printed Circuit Boards*** are typically overlayed on top of other conductive metals. Our objective here is to allow the ***hydrochloric acid (HCl)*** to start dissolving the underlying metals. After about 10 minutes, slowly add ***100ml of hydrogen peroxide (H_2O_2)*** to the solution. This will cause a chemical reaction which will produce off-gassing, heat, but more importantly – it will produce a large number of bubbles which will agitate the solution! This turbulence within the solution helps to dislodge the gold from the surface of the circuit board. It's also recommended that you cover the beaker to contain the fumes and avoid any unnecessary dilution of the acid. Then let the reaction continue for a minimum of 12 hours. Therefore, it would be practical to let the reaction go over night so the students can come back to the experiment the following day. At this point the solution will have changed from a green to a dark black colour. You will then need to add another ***100ml of hydrogen peroxide***. This further dilutes the solution while also rejuvenate the chemical	现在，印刷电路板上的金连接器通常覆盖在其他导电金属上。我们的目标是让盐酸（HCl）开始溶解下面的金属。 大约 10 分钟后，缓慢向溶液中加入 100 毫升过氧化氢（H_2O_2）。这会引起化学反应，产生废气和热量，但更重要的是，它会产生大量气泡，搅拌溶液！溶液中的这种湍流有助于将金从电路板表面去除。 还建议您盖上烧杯以容纳烟雾，避免对酸进行任何不必要的稀释。然后让反应持续至少 12 小时。因此，让学生们的反应持续到晚上，这样学生们第二天就可以回来做实验了。 此时，溶液将从绿色变为深黑色。然后，您需要再添加 100 毫升过氧化氢。这进一步稀释了溶液，同时也使化学反应恢复活力。

reaction. Then repeat this process twice over a 72-hour period. Due to the time, it takes for this process to occur you will likely want to split up your lessons. Have students spend a few minutes addressing the practical requirements of the lab, and then the remainder of the class addressing theory. This could include updating their lab books with observations, procedural notes, and covering the theoretical aspects of the lab itself. After 72 hours the solution will be ready for the next step. At this stage you can pour out the solution into a clean beaker. Keep this solution as it will need to be filtered to remove any gold before disposal. Next, using thick rubber gloves and a water spray bottle you can wash the scraps! Make sure that you inspect all scrap materials to see if there is any gold remaining on the circuit board.	然后在 72 小时内重复此过程两次。由于时间的原因，需要发生这个过程，你可能会需要你的课程分开。让学生花几分钟时间解决实验室的实际要求，然后在课堂的剩余时间解决理论问题。这可能包括用观察结果、程序说明更新他们的实验室书籍，并涵盖实验室本身的理论方面。 72 小时后，溶液将为下一步做好准备。在这个阶段，你可以把溶液倒进一个干净的烧杯里。保留此溶液，因为在处理之前需要对其进行过滤以去除任何黄金。接下来，使用厚橡胶手套和喷水瓶，你可以清洗碎屑！请确保检查所有废料，看看电路板上是否有剩余的黄金。

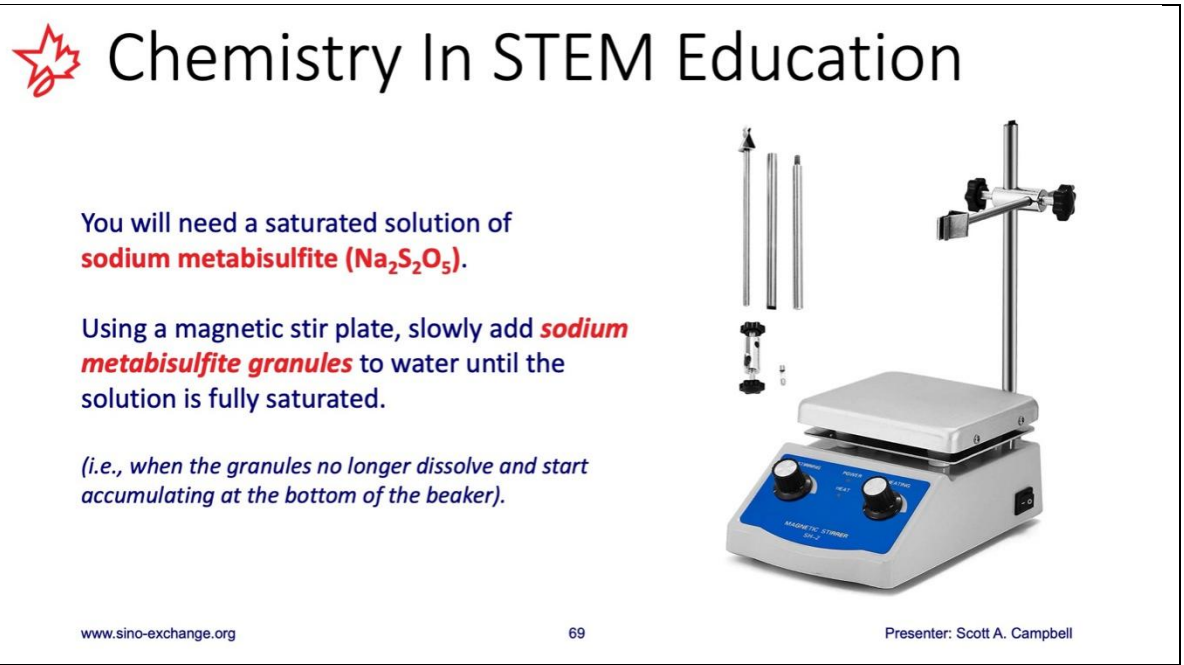


With the scrap thoroughly washed, you are now ready to filter the blacken acid to catch any fine particles in the solution. Poor the solution into a funnel with filter paper in it, or better yet use a vacuum filtration unit like the one shown on this slide. For optimal results, be sure to pre-wet the filter paper before using it. Once the entire solution has been filtered you should be left large gold particulates in the original beaker and some finer gold particulates that have been caught by the filter paper. You can now dispose of the initial acid solution. Please note that there will be dissolved metals such as iron, lead, and cooper in this solution which could be recovered using more advanced recovery methods; however, these methods are much more complex. Moreover, as gold is the most valuable metal, and time is limited it is practical to only focus on extracting gold in an educational setting. Next, carefully remove the filter paper and place it in a clean beaker as it will be full of gold powder. Then let the filter dry. At this point you will have a beaker that has a gold sludge in bottom of it and another beaker with a filter paper full of small gold	彻底清洗废料后，您现在可以过滤变黑的酸，以捕获溶液中的任何细颗粒。 将溶液放入装有滤纸的漏斗中，或者最好使用如本幻灯片所示的真空过滤装置。为了获得最佳效果，请确保在使用滤纸之前预先润湿滤纸。过滤完整个溶液后，应在原始烧杯中留下大的金颗粒和一些被滤纸捕获的较细的金颗粒。您现在可以处理初始酸性溶液。请注意，在这种溶液中会有溶解的金属，如铁、铅和铜，可以使用更先进的回收方法进行回收；然而，这些方法要复杂得多。此外，由于黄金是最有价值的金属，而且时间有限，因此只在教育环境中专注于提取黄金是可行的。 接下来，小心地取下滤纸，将其放入干净的烧杯中，因为烧杯中会充满金粉。然后让过滤器干燥。在这一点上，你会有一个底部有金泥的烧杯，还有一个烧杯，里面有一张装满小金颗粒的滤纸。然而，这种黄金仍然会含有大量污染物。

particulates. However, this gold will still contain lots of contaminants.	



Next, we will remove contaminates form the gold residue. Using 1L beaker, add all gold residue that has been collected and add ***200ml of hydrochloric acid (HCl)***. Then add small amounts of ***nitric acid (HNO_3)*** using a dropper, pipette, or burette so that you do not end up with excess of ***nitric acid*** in the solution. At this point, the gold will start dissolving and you will see red ***nitrogen dioxide (NO^2)*** fumes forming. Make sure that you avoid breathing in these fumes. Once all the gold has been dissolved, filter the solution again to remove any contaminants such as fiberglass and plastic from the solution. Be sure to thoroughly rinse your beaker, funnel, and filter paper with water until the solution runs clear as the residual will contain gold.	接下来，我们将去除金残留物中的污染物。 使用 1L 烧杯，加入已收集的所有金残留物，并加入 200ml 盐酸（HCl）。然后用滴管、移液管或滴定管加入少量硝酸（HNO_3），这样溶液中就不会有过量的硝酸。此时，黄金将开始溶解，你会看到红色二氧化氮（NO_2）烟雾形成。确保你避免吸入这些烟雾。一旦所有的金都溶解了，再次过滤溶液以去除溶液中的任何污染物，如玻璃纤维和塑料。一定要用水彻底冲洗烧杯、漏斗和滤纸，直到溶液变清，因为残留物中含有黄金。



The next thing you will need to do is to create a saturated solution of ***sodium metabisulfite ($Na_2S_2O_5$)***. Using a magnetic stir plate, slowly add ***sodium metabisulfite*** granules to water until the solution can no longer accept any more. That is, when the granules no longer dissolve and start accumulating at the bottom of the beaker. Then add your filtered gold solution to a large 1L beaker. At this stage you can now add the ***sodium metabisulfite*** to the ***gold bearing solution***. The ***sodium metabisulfite*** will react with the ***hydrochloric acid*** in the solution which will create ***sulfur dioxide (SO_2)***. The gold ions will be attracted to the surfer which will cause them to fuse together and drop out of solution as a metallic precipitate.	接下来你需要做的是制作一种偏亚硫酸氢钠（$Na_2S_2O_5$）的饱和溶液。 使用磁力搅拌板，慢慢将偏亚硫酸氢钠颗粒加入水中，直到溶液不再能接受为止。也就是说，当颗粒不再溶解并开始在烧杯底部积聚时。然后将过滤后的金溶液加入 1L 的大烧杯中。在这个阶段，您现在可以将偏亚硫酸氢钠添加到含金溶液中。偏亚硫酸氢钠将与溶液中的盐酸反应，生成二氧化硫（SO_2）。金离子会被冲浪者吸引，这会导致它们融合在一起，并以金属沉淀物的形式从溶液中掉出来。

Chemistry In STEM Education

Allow the heavy gold particulates to settle at the bottom of the container (wait a minimum of 4 hours / overnight).

Conduct a **stannous chloride ($SnCl_2$)** test to see if there is any gold in the solution.

***NOTE:** If gold is still present in an aqueous form you will need to add more of the **sodium metabisulfite** solution.*

The remaining solution will be a translucent brown colour. Carefully pour it into a waste beaker without disturbing the gold particulate at the bottom of the beakers.

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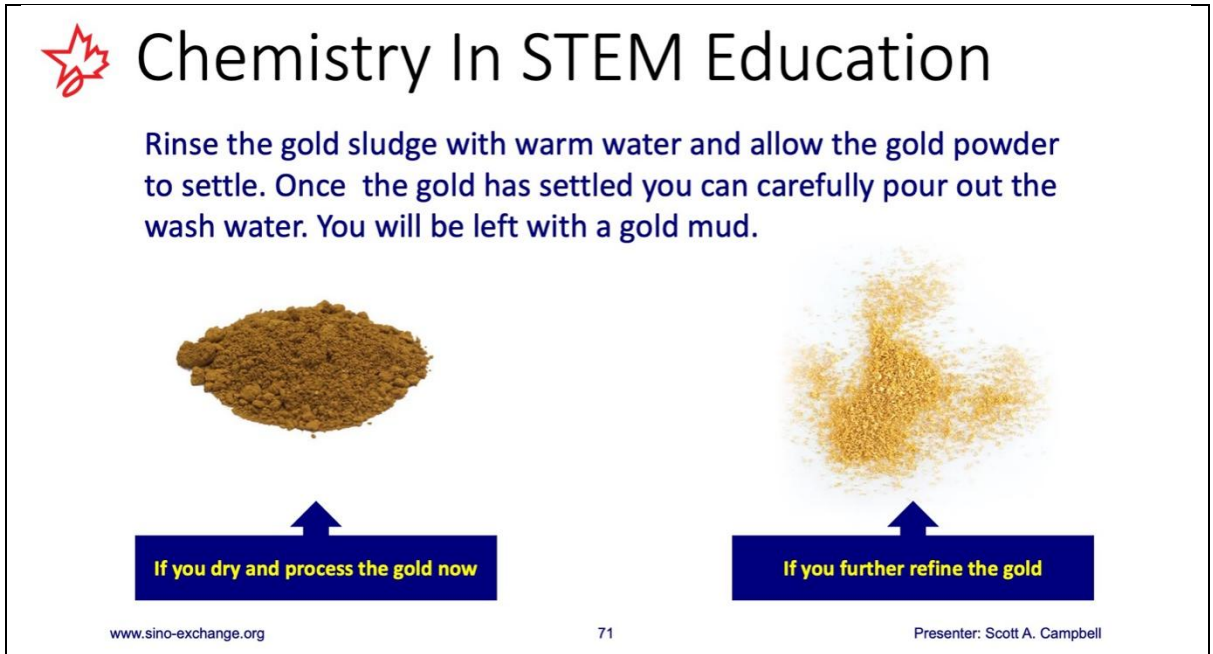
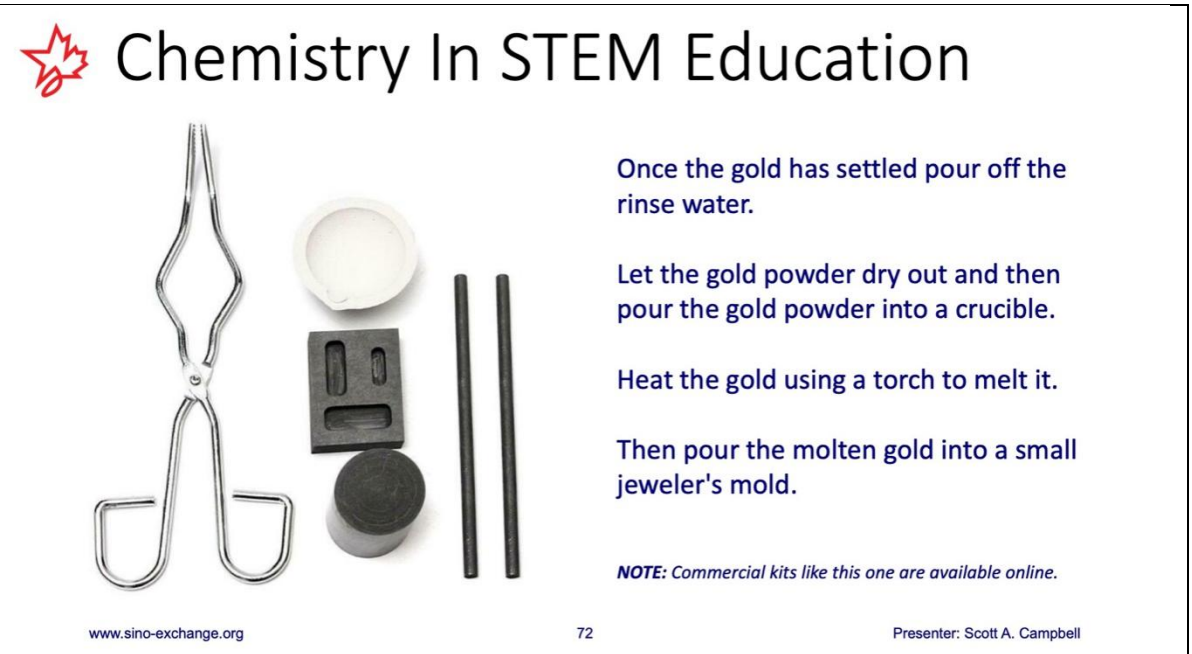
Allow the heavy gold particulates to settle at the bottom of the container. Then wait a minimum of 4 hours or even overnight before proceeding to the next step. Next conduct a ***stannous chloride ($SnCl_2$)*** test to see if there is any gold left in the solution. *The remaining solution should be a translucent brownish colour at this point. Carefully pour out the waste solution into a waste beaker without disturbing the gold particulate at the bottom of the beaker.* Check the waste with ***stannous chloride*** one more time to see if there is any gold left in it before disposal.	让沉甸甸的金颗粒沉淀在容器底部。然后等待至少 4 个小时，甚至过夜，然后再进行下一步。接下来进行氯化亚锡（$SnCl_2$）测试，看看溶液中是否还有金。此时剩下的溶液应该是半透明的褐色。小心地将废液倒入废烧杯中，不要干扰烧杯底部的金颗粒。再用氯化亚锡检查一次废物，看看里面是否还有金子，然后再处理。



Then rinse the gold sludge with warm water and allow the gold powder to settle. Once all the gold has settled carefully discard the wash water. You will be left with a gold mud at the bottom of the beaker. At this stage you cold dry the gold powder, or you could process it further. My recommendation is to process it even further. To continue filtering out the impurities in the gold you will need another ***400ml of hydrochloric acid***. Apply medium heat and stirring. As the ***hydrochloric acid*** boils, it will react with any remaining metals that are in the powder, and the solution will start to get darker. This will be most likely as a result of iron being present in the solution. Let the solution settle and then perform another ***stannous chloride ($SnCl_2$)*** test. If the acid solution has dissolved any gold, you will need to add small amounts off the ***sodium metabisulfite*** solution to precipitate the gold out of the solution. However, it is important to add it slowly as you do not want to precipitate other metal out of solution in the process. Therefore, you will need to keep conducting ***stannous chloride ($SnCl_2$)*** tests to help you identify when you should stop adding ***sodium metabisulfite*** to the solution.	然后用温水冲洗金泥，让金粉沉淀下来。一旦所有的黄金都沉淀下来，小心地丢弃洗涤水。烧杯底部会留下一块金泥。在这个阶段，你可以将金粉冷干，或者你可以对其进行进一步加工。我的建议是进一步处理它。 要继续过滤掉黄金中的杂质，你还需要 400 毫升盐酸。用中火加热并搅拌。当盐酸沸腾时，它会与粉末中的任何剩余金属发生反应，溶液会开始变暗。这很可能是溶液中存在铁的结果。让溶液沉淀，然后进行另一次氯化亚锡（$SnCl_2$）测试。如果酸性溶液溶解了任何金，则需要从偏亚硫酸氢钠溶液中加入少量，以使金从溶液中沉淀出来。然而，缓慢添加它很重要，因为在这个过程中你不想让其他金属从溶液中沉淀出来。因此，您需要继续进行氯化亚锡（SnCl2）测试，以帮助您确定何时应停止向溶液中添加偏亚硫酸氢钠。 然后，完成后，倒入废物，用热水冲洗金粉。然后让金子沉淀下来，像以前一样倒出洗涤水。

Then, once you are done, pour out the waste and rinse the gold powder with hot water. Then let the gold settle and pour off the wash water the same as before.	

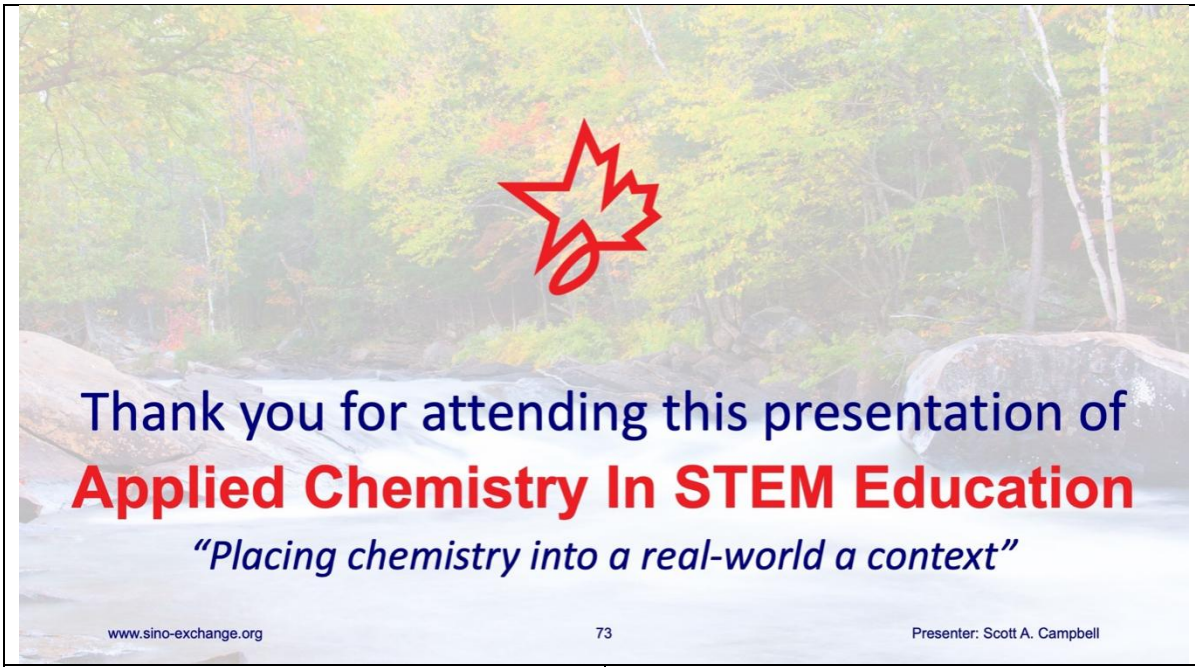


At this point you could melt down your gold, or you can purify it one more time by conducing another round of ***hydrochloric acid***, followed by medium heat, and stirring, followed by small amounts of ***nitric acid.*** After about 1 hour you will have an orange solution. Allow the solution to cool before adding ***sulphuric acid*** which will react with any dissolved lead and will precipitate it out as a fine powder.

Vacuum filter the solution, and be sure to rinse your beaker, funnel, and filter paper with water as they will contain gold. The lead precipitate will be caught by the filter paper. Then add ***sodium metabisulfite*** to precipitate the gold out of the solution. Conduct another ***stannous chloride ($SnCl_2$)*** test to ensure there is no gold before discarding the waste solution. Then rinse the gold powder with hot water again. Once the gold has settled pour off the rinse water. Let the gold powder dry and then pour it into a crucible. Use a torch to melt the gold and then pour the molten gold into a small jeweler's mold. Upon completion you will now have a small gold nugget that will probably be around 20k gold.

在这一点上，你可以熔化你的黄金，或者你可以通过传导另一轮盐酸，然后中火，搅拌，然后加入少量硝酸来再次纯化它。大约 1 小时后，你会得到一个橙色的溶液。在加入硫酸之前，让溶液冷却，硫酸会与任何溶解的铅反应，并将其沉淀为细粉末。

真空过滤溶液，并确保用水冲洗烧杯、漏斗和滤纸，因为它们会含有黄金。铅沉淀物将被滤纸捕获。然后加入偏亚硫酸氢钠使金从溶液中沉淀出来。在丢弃废液之前，再进行一次氯化亚锡（$SnCl_2$）测试，以确保没有金。然后再次用热水冲洗金粉。一旦黄金沉淀下来，就把冲洗水倒掉。让金粉变干，然后将其倒入坩埚中。用火把把金子熔化，然后把熔化的金子倒进一个小珠宝商的模具里。完成后，你现在将有一个小金块，可能约为 2 万的黄金。



That brings us to the end of this presentation. I hope that this in-service program informative and that you have been able to take away several ideas that you can use to design authentic learning opportunities for your students, while also learning how to use chemistry to solve a variety of real-worlds problems. And with that said, I would like to thank you for giving your precision time to attend this presentation of **Applied Chemistry in STEM Education.**	本次演讲就将结束了。 我希望这个在职课程能提供信息，并且你已经能够带走一些想法，这些想法可以用来为你的学生设计真实的学习机会，同时也可以学习如何使用化学来解决各种现实世界中的问题。 话虽如此，我要感谢您抽出宝贵的时间参加 STEM 教育中应用化学的演讲。