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THROUGH THE LOOKING GLASS – VIDEO CAMERA IN THE CHEMISTRY LABORATORY

A look on an intervention between technology and chemistry

Submitted by: Ehud Aviran

To: Prof. Ron Blonder

Department of Science Teaching,

The Weizmann Institute of Science,

Rehovot

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Acknowledgments

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Technology in the service of Teaching

“Alice started to her feet, for it flashed across her mind that she had never before seen a rabbit with either a waistcoat-pocket, or a watch to take out of it, and ***burning with curiosity****, she ran across the field after it, and fortunately was just in time to see it pop down a large rabbit-hole under the hedge.*

In another moment down went Alice after it […]“[1]

Upon their first meet, Alice notices the White Rabbit is always in a hurry: “No time! No time! Have to run!” – In today’s technologically rich backdrop, the classroom cannot remain behind; an isolated island of the old teaching ways in a world that is moving forward, spearheaded by technology. As the science of Chemistry moves forward on its biennial journey, so does the ways of teaching chemistry must keep with the times.

In the laboratory, not once do students find themselves stunned by the overwhelming flow of information, they are required to process – from laboratory skill proficiency to observations made throughout the experiment. This usually brings about a loss of information, as the unskilled student is also faced with social interactions, teacher instructions and other cognitive demands. All this leads to high cognitive load. So high in fact, that sometimes students miss key factors and elements of an experiment. This can also lead to detachment of the student from the laboratory unit, lower motivation and devolvement of scientific merit.

Back to the White Rabbit: He is in a hurry, because wherever he may turn – things are already moving past him, so he must keep running just to keep up (barely) with all that is happening in Wonderland. The teacher’s work can sometimes seem like that endless race, especially in prospect of the advancements in technology: with new gadgets and websites arriving each day to improve our life – but without proper integration and use would become somewhat of a mute, useless artifact. Learning how to properly use and integrate a technological tool is imperative, for both teacher and students – for proper use and yield both better performance (in class and in the laboratory), as well as boost the subject’s image.

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When it comes to educational research, one of the most canonical works belongs to Lee S. Shulman (1986). In his works he wrote about the way teachers arrange their knowledge, on *how to teach a*

[1] The quotes throughout this paper are taken from Lewis Carroll’s *Alice’s Adventure in Wonderland* (1865). London: Macmillan Publishers Ltd.

specific subject matter; he coined the term PCK (Pedagogical Content knowledge) – the bridge between *knowing* the subject (Content Knowledge – CK) and knowing *how to teach* (Pedagogical Knowledge – PK). About 25 years later, Kohler & Mishra (2006) furthered his work to include technology – or what technological tools are required and best used to teach a specific subject matter. The knowledge on *how to teach using the right technology* was termed TPCK[2] (Technological Pedagogical Content Knowledge) to integrate the use of technology into the fold. Bringing about the formal recognition of the age of information to the world of education – when technology becomes another path of learning, instead of just "tools for educational content management" (Voogt, Fisser, Pareja Roblin, Tondeur, & van Braak, 2013) – compare it to using an iPhone as a flashlight, or a temperature logger's probe as a stirring rod. Recently, Blonder and others (2013) demonstrated how proper use and implementation of technology (in that specific case – the use of video clips in chemistry) can lead to not only bettering how teachers teach, but also to their self-efficacy beliefs. Technology can be a tool for improving oneself, as well as improve the way one teaches and learns.

At the beginning of the 90's, Robert Kozma (1991) wrote about the potential technology has to better learning, in aspect of integrating technological tools usefully and skillfully into everyday school work, as well as in the curriculum as a whole. Garratt (1997) later argued, that using technology as a way for pupil-based learning, allows for personal hand-on experience – a way to better learning in respect to traditional teaching. At the end of the prior millennia, Herron & Nurrenberg (1999) reviewed the field of research in science teaching, and pointed out how lacking the research was in the domain of exploring and integrating technology into chemistry teaching. They discussed the matter in a general – and specifically regarding using technology in the chemistry laboratory; those claims were later reinforced by Gilbert *et al.* (2003). 15 Years later, the ongoing effort to map how research treated chemistry teaching (Teo, Goh, & Yeo, 2014) and specifically – teaching within the laboratory – yielded the same results: Too few had took upon themselves to look into the matter.

Of those few, Harwood & McMahon (1997) emphasized on <u>proper</u> integration of technology within the domain of chemistry in school. They showed how that technology could bridge gaps between students, originating from different backgrounds and skill levels – and resulting in higher achievements and better attitude toward chemistry as a subject and the chemistry laboratory. In more recent studies, it was shown that the use of technological tools could improve and optimize learning process in the chemistry laboratory (Seery & McDonnell, 2013; Seery, et al., 2017). On the contraire, it is worth noting, that technology comes with a price: A study aiming to integrate video instructions as a preliminary step to chemistry laboratory (Croker, Andersson, Lush, Prince, & Gomez, 2010) found resistance in the form of the laboratory faculty members. The faculty saw a

[2] Sometimes written TPACK for better acronym abbreviation and pronunciation.

threat to their jobs and income, fearing the administration will opt to replace teaching hours targeted at getting students ready for every experiment, with a video recording.

Another researcher who took upon himself to advance chemistry teaching through technology is David Smith, a professor at York University for chemistry, who is also involved in science education. In 2009 he launched a YouTube channel dubbed ProfDaveAtYork (Smith, ProfessorDaveatYork, 2009) through which he posts videos of himself explaining chemical phenomena and giving online classes relevant to the course material in the courses he is teaching at the university. Smith is using the video platform to expand the reach of his teachings beyond the confines of his class, thus fulfilling the first of his three-step "iTube-YouTube-WeTube" model (Smith, 2014)(shown on the right), aiming at involving his students, students in other universities – and eventually, everyone else – at creating, sharing and learning from chemistry-relevant videos. This working model aims to create interest within each chemistry student, by encouraging them to share their own experience through available channels – thus increasing involvement, immersion and interest within the content creators. In a way, the goal of this work is to expand based on this model.

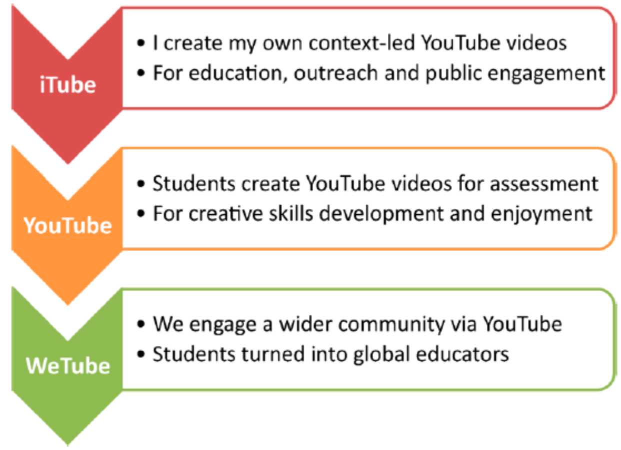


Figure 1. The three step model offered by David K. Smith for involving media in teaching chemistry

The laboratory in chemistry education

"[…] then she looked at the sides of the well, and noticed that ***they were filled with cupboards and book-shelves***; ***here and there she saw maps and pictures hung upon pegs****. She took down a jar from one of the shelves as she passed…."*

It been said (Garratt, 1997), that chemistry is taught through handiwork, and so teaching in the traditional way of board and marker is less adequate when trying to grant the students a sense of the world of matter. Many (Okebukola, 1986; Hofstein & Lunetta, 2004; Hofstein, 2004) have shown that integration of laboratory time and technique within the theoretical curriculum, provided students with the tools to apprehend, visualize and understand abstract notions taught in the classroom – while boosting motivation, uplift morale and instill a sense of curiosity. Allowing for hands-on experience during school hours grants students a change of scenery, a venue to express themselves in ways other than pen-and-paper in a field usually considered demanding and for both mind and concentration.

The chemistry laboratory unit has become a mandatory part of chemistry education in Israel in 2016 (Chief Inspector of Chemistry, 2015). Though it has been accompanying the theoretical parts for quite a few years beforehand (Chief Inspector of Chemistry, 2005), graduating from an experimental unit taught by a pioneering few, to a widespread practice that brought students back to the laboratory time and again. All chemistry students are required to undertake a minimum number of exploratory labs (according to each class' teaching-unit level, as of the teacher's decision) as an integral part of the curriculum for high school chemistry. This is done through a period of three years (10th – 12th grades), intertwined within the weekly timetable. In the lab, students come in contact with the issues, notions and ideas they have met in the classroom, being able to transform theoretical understanding to practical assumptions, realizations and answers to questions – all raised within the lab. Since the introduction of the laboratory unit, the profession prestige has risen, as well as number of participating students. But for all the issues that still plague the use of the lab in chemistry, there are still few that has not received proper handling. One of which is the adaptation of the lab to new technologies, specifically the video camera, and its impact on the laboratory scenario.

Practices in teaching in a chemistry laboratory

Twenty years ago, Herron and Nurrenberg (1999) reviewed the literature in the field of Chemistry Education Research and noted that it lacks in the aspects of understanding laboratory work and the use of technology in the classroom as well as in the lab. Since then things have changed, and as Hofstein (2004, p. 249) has noted: "sufficient data do exist to suggest that the laboratory instruction is an effective and efficient teaching medium to attain some of the goals for teaching and learning science".

The first mention of chemistry laboratory dates back to 1807, when a chemistry professor W. Cullen allowed access to a proper laboratory setting for his students as part of their education at the University of Edinburgh, Scotland. Though Stromyer (in 1806, and others of that time) predated him with laboratory work *per-se*, it was as Liebig had noted how "at that time, chemical laboratories in which instruction was given in analysis did not exist anywhere. What people called such, were rather kitchens, filled with all sorts of furnaces and utensils for carrying out metallurgical or pharmaceutical processes." (Elliott, Stewart, & Lagowski, 2008, p. 145) Later on, Liebig would train generations of chemistry students in a problem-based technique in ways not unlike how graduate chemistry students are trained today – through tackling and solving real-world problems within the chemistry laboratory. Ever since Liebig's days, the understanding that chemistry teaching is closely related to laboratory work has grown, and today few instructors would consider offering a course in basic chemistry without a laboratory component attached. Even so, with the advancement made in the fields of engineering, physics as well as chemistry, a remarkable truth has risen. Due to the hieratical nature of science, as experiments near the forefront of scientific research, the chemistry laboratory finds itself less equipped with proper tools to emphasize those advancements to the students. As a basis of knowledge must first be acquired by the students – for them to understand the meaning of such discoveries, and therefore, the experiments leading toward them. In short: as science moves forward, the laboratory is forced to stay behind, until the level of the students shall be adequate to the skills needed. In high-school scenario, the implication is vivid: students hear about and experience scientific progress – not to be found in their laboratory sessions.

Students' attitude towards the laboratory in chemistry education

In Israel as well as the rest of the world, the impact of the laboratory on science students – and chemistry in particular – has been thoroughly researched, all arriving at the same conclusion (largely) – students love lab work (Turkoguz, 2012). A student would prefer to experience hands-on with the matter at hand, be it physics, mathematics, biology or chemistry – than another lecture or practice in class. Following students around the lab, one discovers that besides doing the actual work, students interact with each other, attempt their own rouge experiments (not mentioned or instructed in the specific lab manual) and find other ways to experiment and thus implement and investigate the subject matter in many, correlating and diverging ways. Or as Okebukola stated (1986): "Doing laboratory work may lead to improved skills, and the acquired skills may promote a more desirable attitude towards such work". He further implies that investing students into laboratory work, in ways that will incur better understanding of – and therefor better attitude towards – the unit, will better their attitude towards the subject as a whole. This can also lead to better self-efficacy beliefs by students; endorse higher motivation for science (as a whole), and chemistry and the laboratory unit in particular. According to Blonder et. al. (2013, p. 289) "self-efficacy can influence the courses of action people choose to pursue, how much effort they invest in a given task, and how long they will persist facing obstacles and failures." – thus maintaining a sense of success while allowing degree of personal freedom of action, gives the students a feeling of achievement, even if there are setbacks and pitfalls.

Using video recording in school scenario

Two years ago, I have submitted an idea to the Fund for Educational Initiatives of the Ministry of Education, and had my idea chosen to be turned into a reality. My idea was establishing a bank of video recorded classes, of which my students could use at any time, any place. They can learn at their own rhythm, and be able to repeat each and every lesson or timeframe for as many times as they want. This I have seen as a truly useful tool for differential education – teaching each student as accordance to their individual needs.

The first time I have set up the camera in the back of the class, went almost unnoticed. It was only when the students took note of the microphone that I was wearing, that they realizes they were videotaped. Even so, pretty soon the camera became a regular member of our sessions, and so the students accepted it as such – while they learned to benefit from the situation. I've began editing and uploading classes to my YouTube channel, *Hamoreh Hamekuvan* (The online teacher) (Aviran, 2017), so they could review lessons past, catch up on ones they have missed, and repeat specific content on their own terms, place and time. Or as one of the students said during their post-work interviews: "we are not technologically unsavvy, nor are we strangers to the camera; growing up in this generation, it is almost a constant companion, and therefor does not affect the way we go about our ways."

In literature, the use of visual media as a teaching aid, and video cameras in particular, is usually viewed as favorable (Turkoguz, 2012; Seery & McDonnell, 2013; Croker, Andersson, Lush, Prince, & Gomez, 2010; Smith, iTube, YouTube, WeTube: Social Media Videos in Chemistry Education and Outreach, 2014; Blonder, et al., 2013). Those can contribute to students and teachers alike, enhance motivation and better learning processes, increase efficiency and boost self-confidence and self-efficacy. Even though research in this field is still considered to be lacking (Teo, Goh, & Yeo, 2014) it is as prominent as it is needed: in an era of innovation, schools cannot afford themselves to linger behind the technological evolution.

Video in the lab: useful tool or a gimmick?

"Laboratory environments equipped with visual tools can improve students' individual and social learning skills" (Turkoguz, 2012, p. 402) When I sought a way so that I could combine the authenticity of the experiment with the added-value of the camera, and came up with the idea of entrusting it to the students' hands. My biggest concern was that the camera would become the heart of the matter, drawing attention from the experiment and reducing it to a video performance rather than laboratory session.

Where all that is not put to words for recording sake, is lost – the camera is an imperative device to be had: without personal interpretation or a tendency to be forgotten or distorted – like with a memory. The camera records exactly what happened, and allows for it to be seen repeatedly, and at a later time. But that is not all – Pasquali (2007) wrote about using video as a way to confer methods in the laboratory, to help alleviate the burden of translating written instructions to discernable action. This can donate to decrease in novelty space and increase efficiency and confidence in the laboratory. Furthermore, in the process of Self-explanation required when explaining what is in view of the camera, forces the students to conduct a personal review of their knowledge and understanding of the matter, in order to convey a proper narrative (Talley & Scherer, 2013) – and eventually tell the story of the experiment, right.

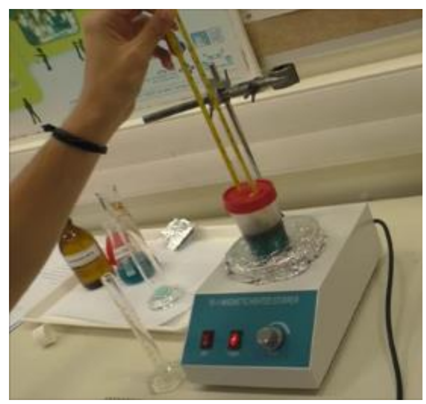
On a different front, making and using recordings of experiments can add to chemistry's stature, boost enrollment and even reach beyond the walls of the laboratory to other students and the rest of the community – but that is a story for another time…

Rationale: What is it all about?

By inserting the video camera into the laboratory, I have intended to boost interest, help learning, bridge attendance gaps and shift some of the power vested in me as the class leader to the students' hands, thus motivating them to engage themselves more in the laboratory – bring more of themselves to class.

It all began two years ago, when I have submitted an idea to the Fund for Educational Initiatives of the Ministry of Education, and had my idea chosen to be turned into a reality. My idea was born from need: prior to submitting the idea, I was bedridden for a month and a half, due to surgery requiring recuperation. This has led me in search of new ways for which to communicate with my students (for this happened in the middle of the school year). I have found the online classes (given from my bed at the time) had a very positive impact on my students, even those who did not attend those online meetings, for the sessions were recorded and uploaded to YouTube later on. Thus came the idea to establish a bank of video recorded classes, of which my students could use at any time, any place; so they can learn at their own rhythm, and be able to repeat each lesson or part of it for as many times as they want. This I see as a truly useful tool for differential education – teaching each student with accordance to his or her own individual needs. When I sought a way to transfer the camera into my students' hands, the laboratory seemed a natural venue through which to do so, and to my delight – my students responded gleefully. At first, I was not sure to what extent this endeavor will promote all those goals I have mentioned before. But as time went by and more teams of students received the camera as their chaperon, I have realized there's merit in it all. Giving the students a tool through which they can sound their own voice, expose their thoughts and conceptions (and sometimes – misconceptions) while doing chemistry work – allows for me, the teacher, a perspective I have never thought I'll get. This also lead to better attitude towards the laboratory and the subject among my students, and even boost self-value for some students (more on that, later on).

Method



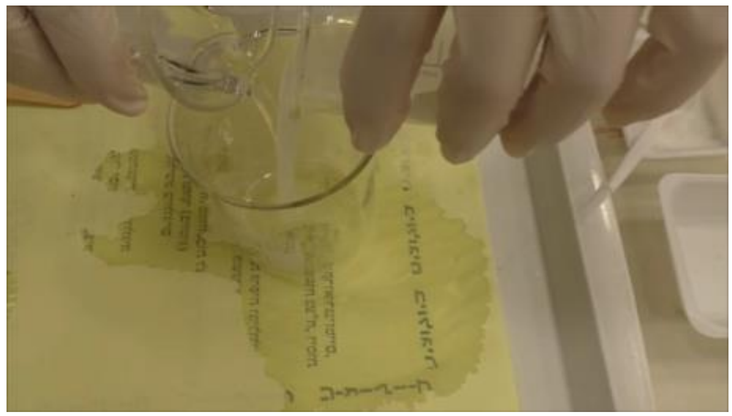
"Begin at the beginning," the King said, very gravely, "and go on till you come to the end: then stop."

The intervention took place in an urban high school in the north of Israel, included 17 12th grade chemistry students, all taking chemistry as an elective subject for a 5 unit (YACHAL) Bagrut level. The class was taught by the same teacher for the 3-year period (10th-12th grades), and had some experience with laboratory work in the year prior to the intervention (2 experiments out of the mandatory 8 needed for 1 out of the 5 units). The students paired into teams of 2 for each experiment by their own accord, choosing a different partner for most experiments. Of the 17 students in class, only 12 students (70.6%) participated in recording their lab experiment; two more had a failed attempt in recording (misuse of the video camera led to not acquiring any useful footage). Of the 10 students that recorded successfully, 2 students had recorded an experiment that was not included in the final oral exam.

Interviews were conducted a few days to a few weeks after each recorded experiment (pending schedule limitations by the students). The interviews were mostly half-constructed, with basic questioning-line set to discover how the students reacted to the camera in the laboratory scenario; 10 students were interviewed, all in teams of two. The interviews were recorded and transcribed.

The experiments included in this year's students portfolio: (two experiments were not included for the oral exam for they were of a lower level than necessary)

- Calculating the ratio in a hydrate formula (not included in the final oral exam)
- Calculating the volume of hydrogen gas in room conditions – redox reaction with magnesium and hydrochloric acid. (not included in the final oral exam)
- The Vanishing X – a reaction kinetics experiment with hydrochloric acid and Sodium thiosulfate
- Powders in a Bag – acid-base reaction with citric acid and sodium bicarbonate
- Surprising Blue – a clock reaction of iodine and starch
- Popcorn – an experiment in heat transfer and reaction kinetics
- Turquoise is my color – redox reaction, kinetics and thermodynamics, with aluminum and copper sulfate.
- Foam Snake (Elephant Toothpaste) – disproportionation reaction with hydrogen peroxide and potassium iodide.



Data analysis

Both in-lab video recordings and post-lab audio recordings were made in open conversation scenarios, thus no construct could be instilled upon them for comparison. Therefore, the general context was examined as well as reference to specific citations from the speakers. This was done to determine level of understanding, implementing and use of learned subject material as well as lab skills – but also to shed light on student attitude towards chemistry, the laboratory, the use of the video camera, team work etc.

Video analysis: based on the workframe set by Blonder *et al.* (2013) for event mapping on a recording, the general theme of each even was noted, and the overall number of likewise events were counted. The videos were viewed several times in order to map relevant issues, and five categories were noted: (1) workings and proceedings of the experiments itself; (2) observations and explanations; (3) interactions within the team and other class members; (4) laboratory skills and technique; (5) personal thoughts and reflection.

Interview (audio) analysis: based on the work of Blonder & Dinur (2011) and Hamza & Wickman (2008) on interviewing students, the transcripts of the recorded interviews were read through and coded. Five categories relevant to the research were noted: (1) the use and influence of the video camera; (2) workings and proceedings of the experiments itself; (3) interactions within the team and with other class members; (4) creating content for future students, and responsibility; (5) personal thoughts and reflection.

Findings & Results

Qualitative results

Most of the students (9/10) noted the integration of the camera had a positive impact – some said that the camera actually helped them in preforming the experiment, while some reported having no effect of the camera on their experiment at all. Only one (10%) student reported adverse effect, and that the camera had heavily burdened her laboratory experience. All the teams who participated had improved in regards to skill in the laboratory – be it the skills required for the experiments (sampling, apparatus handling, making observations etc.), camera using skills, thought communication skills and more. In one case, due to technical and other difficulties, the team had to re-do part of the experiment in a different conditions, meaning – in a complementary session with no other students around; therefore no surrounding social interactions were relevant in this case. With this exception, all the footage recovered from the intervention displays positive interactions between the recording team members themselves as well as with other students. A surprising result appears in later videos – when the recording team meets students who participated another earlier recording: the students tended to voice their thoughts, opinions and actions when in camera view, as to enrich the recording being made at the time – even when they were not of the recording team. They have also made their notes visible (and elaborated on them), and explained the logic of their process.

Quantitative results

Out of all the students who participated in the intervention, only 2 chose to not show their faces on camera (had their hands filmed only). As can be seen in Table I, most of the students related to the proceedings of the experiments (1), ranging from a simple mentioning or noting of their actions, and sometimes their importance; to a full portray of steps needed for each phase of the experiment, as plotted in the guidelines. This is also the case when it comes to observations and interactions with other students (3) – most of the time, the teams kept in mind the need to commentate over what is going on in front of the camera, be it important or not… Even so, the teams lacked in the aspects of laboratory skills (4) and thought voicing (5): apparently, it was too much stating-the-obvious for them.

> "TO BE HOSENT, WE ARE OF THAT GENERATION – IT IS NOT LIKE THE CAMERA IS SOMETHING NEW TO US, OR SPEAKING IN FRONT OF ONE IS; WE ARE VERY COMMUNICATIVE. SO TALKING TO THE CAMERA AND SAYING EVERYTHING WE DO AND DEMONSTRATE IT ALL – IT ALL COMES NATURALY FOR US."
>
> – G., 18 Y.O. CHEMISTRY STUDENT

In afterthought, things look different: as portrayed in Table II, most students gave specific attention to the inner proceedings of the experiments themselves, as well as recounting thoughts from the process of executing the experiment. As mentioned before, all of the interviewed students had something to say about the camera in the laboratory, and how it had affected their interactions with their colleagues.

The average score of the experiments' portfolio for the entire class is 79, while the average score for the students who participated in recording their laboratory sessions is 87. The average score for the experiments recorded (6 out of 8 in the portfolio) is 78.

In the oral exam, out of 10 students who recorded their experiments, only 3 (33%) chose to be tested about the experiment they were filming. the average score is 88 for the entire class while the average score for the students who participated in recording their laboratory sessions is 98. Since the credit each student received was for the exam as a whole for three different experiments, comparing final grades for this task in comparison to lab selection, is without merit.

Table I – Video Recordings

Category	Number of students	Examples
(1) workings and proceedings of the experiments itself	8/10	• Explaining steps in treatment of hot crucible after a reaction (does not appear on experiment written documentation and guidelines) • Showing calculations steps for several sections of the experiment report. • Noting the working theory and how the experiment is meant to prove it.
(2) observations and explanations	8/10	• Noting change in color, texture and odor of the treated material (the latter cannot be observed over the video)
(3) interactions within the team and other class members	8/10	• Going around the laboratory, asking other teams questions and talking to them. • Filming other teams' experiments as reference (to compare).
(4) laboratory skills and technique	6/10	• Practicing picking up a crucible with tongs • Voicing the proper use and importance of different steps in the experiment, while executing them on camera
(5) personal thoughts and reflection	6/10	• Reflecting about the reaction that took place – "what we will see here is the evaporation of water, by the change in the color of the solid" • Concluding the video with closing remarks: "well friends, you are done with us for today. Hope you had fun!"

Table II – Audio Recordings

Category	Number of students	Sample quotes
(1) the use and influence of the video camera	10/10	"I also felt, that the fact that we are talking [voicing their thoughts] for me it was part of what I was thinking. Like, I think I need to do something, and when I said that I suddenly something changed and I realized – I could have ruined the experiment just now. Just because we are talking and cooperating, and saying what we need to do now, and explaining each and every step, this contributed to the success of the experiment. Otherwise we could have gone wrong and do other things; because the mind – it races" "See, it's a fact – since we had the camera, somehow we were the ones to finish first, and somehow we did it the best. I think this camera is a magic camera." "Every time I had the camera – somethings went wrong! [...] why I hate the camera? Because every time you have to explain everything and that disrupts my concentration. And I feel myself repeating myself and I get confused…"
(2) workings and proceedings of the experiments itself	8/10	"you see, instructions are not always… you don't always get what you need to do" "Q: what if you WERE wrong? A: even better, if you think about it – everyone would have known what NOT to do… just plainly talking I would walk the, through it, explain what I did wrong and then repeat it, this time correctly, and say "this time do like so"." "This… because this is me, and I like to change things [in the experiment], especially enhance them. You can ask [her partner], after each iteration I would take another spoonful of material, just to add to the reaction, too see what will happen. Love it, crazy about it."

Category	Number of students	Sample quotes
(3) interactions within the team and with other class members	9/10	"…what, that is helps? More in a friendly kind of way – so we got to share with the reminder of the class where we were. It also gives proportions, that we are on the fourth iteration and they are only at the second… it does gives one an indication of the amount of work needed. Also, me and G. [her partner] bonded better… so it was more fun doing the experiment, and I also think that it helps for the part you get to see in the video can help reconstruct the experiment we preformed. Not just for us – for everyone: the whole class did the experiment. So if they can review it later, and they forgot something in, say, the qualitative observations, they can reconstruct it. You just can't rely only on memory in that aspect – and you don't have to, because it videotaped." "…besides, that whole camera thing caused massive cooperation. Big time. Q: just between you two, or did others came over to 'help'? A: I think they were jealous… nah, I think some people around us got all excited."
(4) creating content for future students, and responsibility	7/10	"We felt – at least I felt – responsible, because I realized that there will be other people watching this. And I know that my [little] brother wants to take up chemistry when he will have to choose subjects [for high school]. And I've said that when he'll see my video, and I do want that somewhere. Beyond the jokes – he'll learn. Because sometimes things go awry in experiments. And say, what G. [her partner] did, training with the cup, that is something I at least would not think about beforehand. So as we go along, with the camera in tow […] when we had to actually document each step, I can see how this helps, and how one can get better. Also for other teams" "Only when it turned out to be good – I watched it again at home, and thought to myself, if I'll show this to someone who's a student sent year, then he'll learn from it, know what to do, this will help him. Because before an experiment you sometimes get confused, there is some misunderstanding regarding the experiment itself, what to do and such. Now that you can watch this, you realize it is much easier."

Category	Number of students	Sample quotes
(5) personal thoughts and reflection	10/10	"it made me realize – after one iteration I was all over it, I didn't have to think about it again, look in the instructions and such; I know what to do… I was focused because I did it so many times, and I felt calm because I had experience" "I had to wake up early to school – when I was supposed to come to school at 10:30, instead I had to get up to the first class! [which is three hours before] Now, when I wake up I tell myself maybe I'll go back to sleep, but then I remember – no, we have an experiment today just because I botched it the previous time and that is very irritating!"

Limitations

The Research & Intervention

This endeavor was undertaken over the course of a single year, by a single class, under a single teacher – with no control or reference group (comfort group). Even within the class itself, in every experiment only one team was recording; this prevents cross-referencing data collected on the same experiment from different teams, and also carries an important point to notice: how would that team preform differently in that experiment, had they not used the camera? The recording team also drew more of the teacher's attention, for technical and practical reasons. Some student's experienced technical difficulties (with the camera) that burdened instead of aided them in the execution of the experiment. As for dividing the students into work team,, in a few cases the same teams members worked on more than one experiment, and in other cases teams of three worked together instead of two, resulting in an incomplete mixing of the students.

One aspect I did not foresee by inserting the camera to the laboratory was the social interaction factor. All the teams reported having wider interaction scope with other students around them in the laboratory, compared to working without it. This had led to some interesting (and funny) moments, but also drew some time and attention of team members from preforming the experiment at hand, in favor of those interactions. In some cases, even leading to lagging behind other teams thus causing frustration and indignation.

Also, the assessing and grading process of the students portfolio was done by a single teacher, with no external feedback on the grading scheme used or it internal congruence. And as mentioned before, since the grades refer to the portfolio and the oral exam as a whole, extracting information regarding specific experiments – the one that was recorded by that team – is meaningless.

Data Collection & Analysis

Date collection was based only on the input from those students who elected to participate. Since the interviews were conducted under the restrictions of the student's schedule, most of it transpired during the second half of the school year, when the students have minimal schedule to show up to. The interviews were usually time limited and not in a favorable scenario: other students kept coming on and interrupting, background noises and other obligations the interviewed students had disrupted their concentration, and more. In addition, the interviews were not constructed, and so not all of them yielded the same amount of information or regarded the same points. Therefore, date collection was lacking, and so some insights and correlations are amiss – a full investigation will lead to better understanding of the aforementioned dynamics and interactions.

As for data analysis, some deviations may occur, as the model is adjusted and not novel to the cases (constructed for a different research). In addition, this being a mainly qualitative-based research, some evidence can be viewed in different ways, leading to an inherent bias one must consider while reading it.

What should have been done differently?

The aspect most noticeable in its absence is proper and coherent date collected from the student, ergo – pre- and post-intervention impression collection tool (test, questionnaire, etc.). For future studies I recommend developing and conducting such a step prior to the beginning of any laboratory work with (or without) recording apparatuses, to have a better grasp on the *change* the students went through, as well as implication on the intervention itself.

When it comes to using new instruments in any scenario, let alone the laboratory scenario, it is recommended to conduct an introductory phase – allowing the students to work with the device beforehand. This would diminish novelty space, allow for better usage of time and resources in the laboratory and better the effectiveness of the device – the aim for which it was introduced in the first place. If the students are less occupied with toying with the camera they can be more concentrated on preforming the experiment while utilizing the camera properly: voicing their thoughts, explaining what is viewed and the actions there are preforming on camera. Their overall experience will be much more positive, leading to better attitude towards the camera, the laboratory and the subject matter at hand. In retrospect, it was preferred to order all students to record every experiment by their own smartphones' cameras, and then pool all the footage to a central site (for both ease of access and for attendance). In addition, instructions that are more detailed would have resulted in a more coherent videos produced, as not all teams engaged the same level of involvement with the experiment, regarding matters such as process explanations, observation noting and commenting on thoughts. The recording team interviews would have been better preformed immediately after the experiments took place, and a follow-up interview could have been considered at the end of the school year, this time individually.

Discussion & Conclusion

How the Presence of the Camera affects the Students' Learning

While the camera itself is no stranger to the students, putting it in the laboratory space required some adjustment from them – since this represent a clash of different aspects of their world (school and social media, usually). Furthermore, the need to implement new skill in the laboratory surroundings created a cognitive load, which without proper mediation might have certainly caused the opposite than desirable outcome – alienation of the students from the laboratory instead of increase in familiarization.

When asked directly by the teacher, the students answered the questions to the best of their ability, while trying to maintain the necessary construct as taught in class. However, when the need to explain their actions and verbalized their thoughts on the matters recorded in the experiments, they found interesting and unique (and sometimes wrong) ways to convey their understanding which they based their answers upon. This allowed an authentic way to reveal misconceptions and knowledge schemes, and shed some light on how the students implement what was taught in class.

When the students were required to repeat or elaborate on an experiment with the camera at hand, it appears that they gave some thought on how to portray certain things and explain others, such things they might have overlooked on their first time. Special note was given to the correctness of their explanation of relevant phenomena, and what parts on the experiment needs special attention regarding experiment how-to and laboratory skills – this in accordance to what is known on how the students create and adjust a personal narrative (Talley & Scherer, 2013).

The Camera's Effect on Study Processes and Environment in the Laboratory

Not to surprise anyone, but most students like to be on camera. Some like to be the center of attention, even if they were not there to begin with. One of the students, I considered a humble wallflower, turned out to be quite the camera diva – quite so that it became a laughing matter, when every session, the recording team had to stop filming from time to time because she kept finding ways to interject herself into the frame. (She was well aware of the matter, and kept at it as a folly)

Using and controlling the camera puts newfound power in the hands of the students (Croker, Andersson, Lush, Prince, & Gomez, 2010), which brings them to the forefront of the presenting stage – especially those who tend to avoid it. This should be treated with care, for otherwise can be turned to a tool for bashing thee bashful – even though evidence from this intervention suggest a positive effect to be paramount, the potential for harm cannot be overlooked.

As for environmental pull, the camera holds promise for newfound interactions in the class scenario – students who never spoke to each other now find common ground, as each team wants their experiments to succeed and find the teacher's favor; but also for their video to create a buzz so that everyone will watch it. The thoughtful collaboration between comedy and science is key, and everyone wants to be a star – even if it is only in the chemistry laboratory, or until the next video comes out.

The Students as Educational Content Creators

In light of Prof. David Smith's model *"iTube-YouTube-WeTube"* (Smith, 2014) presented earlier, the first step of the model (*iTube*) has already been started as of two years ago, with the creation of the video recording initiative (Hamoreh Hamekuvan, 2017). With this here described intervention, the second phase (*YouTube*) comes into play as the students create their own content. It is high time for the students to take initiative as we move towards the third act (*WeTube*), thus creating a community of content creators, to be shared and debated as a learning tool.

As aforementioned, most of the students enjoyed working with the camera and noted the positive aspects of the experience. When asked to regard the future use and value of their produced videos, they noted its value for future generations of students as a learning tool and as a preliminary step for each experiment. When further asked on the matter, the students emphasized the ways in which they chose to share their experience with future students, based on the understanding of the value such recording hold for prosperity. This also find footings in the portfolios' dissection: students who scored higher showed greater investment in their recordings and made greater effort to accent what they saw as important in their experiments.

How the Camera Can Be Used to Glimpse "Behind the Scenes" of Learning

Since the camera is a familiar artifact, the students – as original and creative content creators – are free to express themselves in ways, not common in the presence of the teacher and even other students. Those individual ways can lead to the uncovering of personal, private thinking pathways, usually not exposed through other means or in other scenarios. By combining the technological tool with a stimuli-rich environment and an after-the-fact diagnosis, an abundance of worthwhile information can be acquired – from misconceptions to class dynamics. This endeavor, if done as a matter of routine, can allow for the teacher a peek into the inner learning mechanism of his students, recognize and address errors in acquisition and installment of learned concepts, as well as be alerted to any wrong-doings in his class. The handling of the acquired information should be done delicately, otherwise the students will refrain from participating in future sessions involving the camera, as a potential spy on their ways.

The Bottom Line – Conclusion

For many years, students saw chemistry and its laboratories as "difficult discipline and they have difficulty in understanding the concepts" and that "the contents of chemistry laboratory classes are boring, out of date and lacking [in] the dynamism" (Turkoguz, 2012, p. 402). In the age of technology, is it imperative that the chemistry laboratory in particular, will keep up with the times as "the most effective means of overcoming boredom is to gain skills in a greater, more interesting context to the student" (Elliott, Stewart, & Lagowski, 2008, p. 147). The camera has an incredible potential as both a recording and a learning tool. If utilized thoughtfully, a teacher can use it to learn more about his students' thinking-works and team-works – all because the students tend to share, show and tell in front of it. This work has shown that, along the lines of current and upcoming research trends (Blonder, et al., 2013; Seery & McDonnell, 2013; Pasquali, 2007). Based on the model suggested by Prof. David Smith (2014), the described intervention has made students into content creators, thus staging them at phase two of the model (iTube-**YouTube**-WeTube) and setting the stage for phase three, creating a community of learners and spreading the word of chemistry.

Practical use for the ideas discussed in this paper can include implementation of video recordings in the laboratory as a matter of routine, editing and using experiment footage as an *a posteriori* learning situation, recording of videos at home and more. As for theoretical research, the realms of video technology as teaching aid, the laboratory as a technology and stimuli rich environment and the implementation and use of the video camera as a clandestine research tool within the classroom (to mention a few) – have not yet to be fully explored, and there is much work to be had in them.

Technology can be a wonderful venue for teaching and exposing our students to the world, but only proper use and handling can traverse a gimmick into a tool. When every day new ideas give rise to new technology, so does the course of the technological teacher should be ever changing, as the White Rabbit said to Alice:

"My dear, here we must run as fast as we can, just to stay in place.
And if you wish to go anywhere you must run twice as fast as that."

Recommended Practical Application

This work is based on the vision of a prior researchers and an idea born from need. Nevertheless, recommendations for practical use are in order, for what is an idea – without tools to carry it out to the real world and make it a reality.

Recommendations for the laboratory

As all laboratory sessions are accompanied by proper (mostly written) guidelines, it would be advisable to accommodate for instructions of use for the video camera as a recording and documentation device. This should include specific instructions on proper use and safety precautions regarding the camera in the laboratory setting; what to note while recording an experiment, and when to give special attention to different parts of the setting; how and when to use the camera as a measuring tool (for timekeeping, for example) etc.

The footage shot by the students can be pooled into a central reservoir – accounting for both recorded evidence and attendance. The centralization of all recordings can also raise motivation, for when one team posts their footage others can see and compare – thus instilling a sense of competition as well as team spirit – all the while allowing for easier analysis and comparison.

As a preliminary means, it is advisable to conduct specific task regarding use of the camera – especially if it is the smartphone's camera – in the laboratory setting. This preliminary task shall not be graded, as it is meant to familiarize the students with the features and limitations of the video camera as a tool.

Recommendations for future use of video camera

If the camera shall become a companion for the students in the laboratory as it is in their life outside its walls, it is best to find ways to weave it into everyday school (and more specifically, chemistry lessons) routine and schedule. Having the camera as an ever-present object at the back of the class, recording each class session – will result in the students not minding it as much, all the while being aware that there is a recording of each lesson, ready and available to use if case need be.

Experiments guidelines can be laid out in video form, with recorded experiments allowing for students to be able to prepare themselves better for future lab sessions by reviewing those experiments, noting technics as well as relevant material.

The next desirable step is to break the chemistry out from the confines of the laboratory, and bring it closer to home – with experiments in the kitchen, the garden and on the streets. Students recording experiments done in their home surroundings will increase familiarity, boost self-efficacy and create a drive force for learning in everyday backdrop. When the laboratory can be everywhere, and anyone can become a scientist – the will to shoot, share and explore will increase while novelty space will decrease (Orion & Hofstein, 1994).

Recommendations for future research in the field

As mentioned before (Herron & Nurrenberg, 1999; Teo, Goh, & Yeo, 2014), the research in this field is an abundant source of insights for practical educational purpose – but it is as lacking as it is rich. The use of the video camera as a means to uncover learning paradigms and misconceptions, through a silent yet vigilant onlooker, will allow for teachers to find out what their students really know; it can also allow for better understanding of class and team-building mechanisms and interactions. Since the camera can bring about the decrease of novelty space, it has the potential to bring students (and the public as a whole) closer to science (and chemistry in particular) – thus research regarding motivation, attitude toward science in general and chemistry especially, and even science literacy can find an ample source for prominent research in this venue.

As for the long term – longitudal research on the effect of video recording and use among chemistry student, and the overall effect it carries on the broader public, can hold interesting insights. Those can include self-efficacy among video makers, rise of interest towards science among the general public, increase in the familiarity of the subject, impact on literacy as well as the value of science in everyday life, and more.

A glance to the future

"Would you tell me, please, which way I ought to go from here?

That depends a good deal on where you want to get to, said the Cat.

I don't much care where--, said Alice.

Then it doesn't matter which way you go, said the Cat.

--so long as I get somewhere, Alice added as an explanation.

Oh, you're sure to do that, said the Cat, if you only walk long enough."

Even today, there are initiatives vying to incorporate technology into education in any number of ways. In the technologically rich world we live in today, the amount of distractions and interestcatching artifacts that surround us constantly – it is important for educations not to stray behind, and in this condemn itself to become mundane, boring and obsolete. I do not imply that education should become an entertainment venue, but with the changing of the times – so our teaching must change. As for the specific matter at hand, I suggest developing a way to incorporate the video camera as tool for learning, and not just for plain recording. The video camera can be used to pick up wavelengths undetected by the human eye (point a TV remote towards a smartphone's camera and press a button, see what I mean). Alternatively, with the appropriate add-ons, can be used to record chemical phenomena at the microscopic level; this is especially befitting a school with limited resources, for a whole class can share an image caught by other means – and explore it on their own personal time and place. For as long as students will use their cameras, the bank of information will grow, allowing their teacher for a better understanding of their thinking paradigms and finer tuning of the teaching each and every student require. As students will emerge from their traditional place as information receivers and move to a more rewarding spot as knowledge creators, education will move forward with them; the video camera curriculum is but one way to bring this along, and make it fun too.

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The pictures in this works are all outtakes from the video filmed by the students during the research.

