Digital Learning Network (DLN) - 2015 Emerging Technologies Benchmark

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EXECUTIVE SUMMARY

In recent years, it has become clear that the use of evidence-based practices is mandatory in any federally funded program or activity; they are specifically mentioned in the guidance provided by the Committee on STEM (CoSTEM). The guiding question of this document is: **What technology (hardware or software) might be viable for use by NASA and other Federal Agencies for the digital expansion of educational programs on a nationwide scale?** The topics surveyed are as follows: gaming, social media, synchronous video (i.e. videoconferencing / webconferencing), asynchronous video (i.e. video sharing sites / traditional television), virtual learning environments (i.e. online courses / MOOCs), and mobile apps. Primary research for full-text scholarly articles was conducted via the Education Research Complete periodical database, a compilation of more than 1,400 relevant journals as well an additional 550 books and monographs with the database going back as far as 1900 and full-text going back as far as 1930. This document provides a brief overview of the state of each technology with respect to educational use then makes 18 recommendations.

Exhibit 1- Summary of Recommendations

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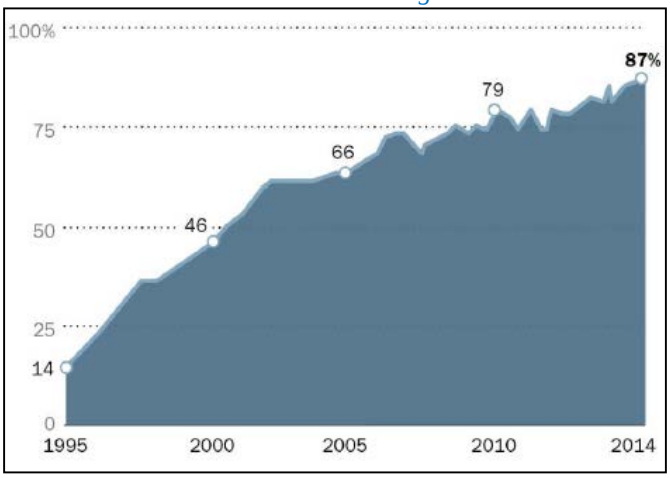
INTRODUCTION

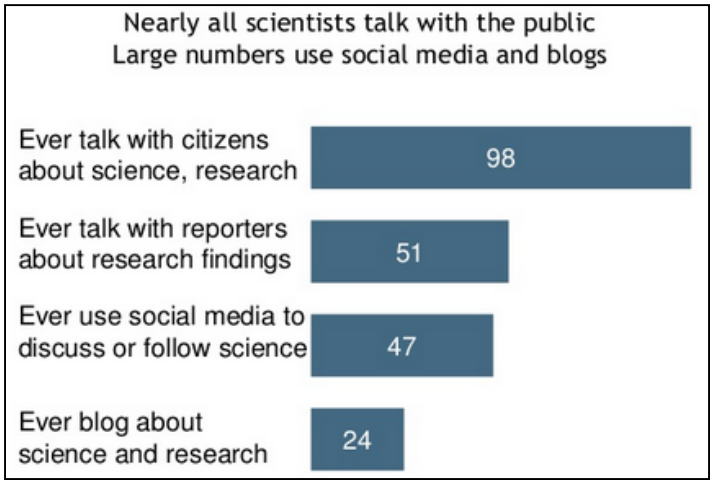
In the past year, the White House has been vocal about the desire for a "free and open Internet."[1] This attention is predicated on the increasing ubiquity of the Internet in the lives of Americans, as demonstrated in the graph below.

Exhibit 2 - Internet use among Americans[2]



Beyond its association with the Executive Branch, the Internet is important to the National Aeronautics and Space Administration (NASA) in that nearly half of all scientists engage the general public via social media and nearly a quarter of all scientists use blogs for the same purpose.

Exhibit 3 - Scientists and the Internet[3]



Consequently, there is a massive existing audience for any infrastructure to further enable or enhance Internet-based outreach and education across science, technology, engineering and mathematics (STEM). Within NASA, the Digital Learning Network (DLN) is striving to become just such an infrastructure – an infrastructure that could easily grow to serve all Federal Agencies.

In recent years, it has become clear that the use of evidence-based practices is mandatory in any federally funded program or activity; they are specifically mentioned in the guidance provided by the Committee on STEM (CoSTEM). The second coordination objective of the CoSTEM 5-Year Strategic Plan[4] is to:

> Build and use evidence-based approaches. Conduct STEM education research and evaluation to build evidence about promising practices and program effectiveness, use across agencies, and share with the public to improve the impact of the Federal STEM education investment (p. viii).

Additionally, the plan insists that:

> Programs will rest on or scale up evidence-based practices. Findings about effectiveness will be shared, along with research-based understandings, and where indications of success are strong, agencies will be encouraged to act upon them" (p. 14).

This document serves as a survey of the recent research literature for that evidence base.

PURPOSE

The purpose of this document is to address the following Statement of Work (SOW) requirement:

Benchmark emerging technologies to support connecting students and NASA on an annual basis to include trends that address social media, gaming, traditional television, and virtual environments. (SOW 3.0.10)

In other words, this document surveys peer-reviewed and other reputable literature in order to examine possible directions for the DLN. The guiding question of this document is: **What technology (hardware or software) might be viable for use by NASA and other Federal Agencies for the digital expansion of educational programs on a nationwide scale?**

METHODOLOGY

Primary research for full-text scholarly articles was conducted via the Education Research Complete periodical database, a compilation of more than 1,400 relevant journals as well an additional 550 books and monographs with the database going back as far as 1900 and full-text going back as far as 1930. Education Research Complete covers the areas of curriculum instruction, administration, policy, funding, and related social issues. The database provides indexing and abstracts for thousands of journals. Topics covered include all levels of education from early childhood to higher education, and all educational specialties, such as multilingual education, health education, and testing. Other scholarly repositories consulted were the Education Resources Information Center (ERIC)[5] and the What Works Clearinghouse (WWC)[6]. As this report sought to understand "the next big thing," other forms of reputable literature were also examined, due to newness or limited availability of the technology. In order to clarify the differences between these types of literature, the following definitions are provided:

- **Best Practices** – peer-reviewed research that utilizes experimental, quasi-experimental, longitudinal, or meta-analytic methodologies
- **Promising Practices** – other peer-reviewed research, typically descriptive case studies or theoretical treatises
- **Emerging Practices** – other reputable documents, such as reports from grant-funded programs, journalists, and industry leaders

Broadly speaking, most of the literature that was reviewed qualifies as promising practices, being either case studies or pre/post quantitative methods with significant limitations such as lack of a control group.

LIMITATIONS

Topics

Given the explosive growth of technology, it is impossible for any single study to encompass all possibilities. For example, this report explicitly excludes:

- Rapid Prototyping / 3D Printing
- Programmable circuit-boards (e.g. Arduino, Raspberry Pi, BeagleBone)
- Robotics
- 360° / Spherical Video
- 3D Video

Certainly, the above as well as countless other topics could be addressed, but those will be reserved for future iterations of this annual report.

The Digital Divide

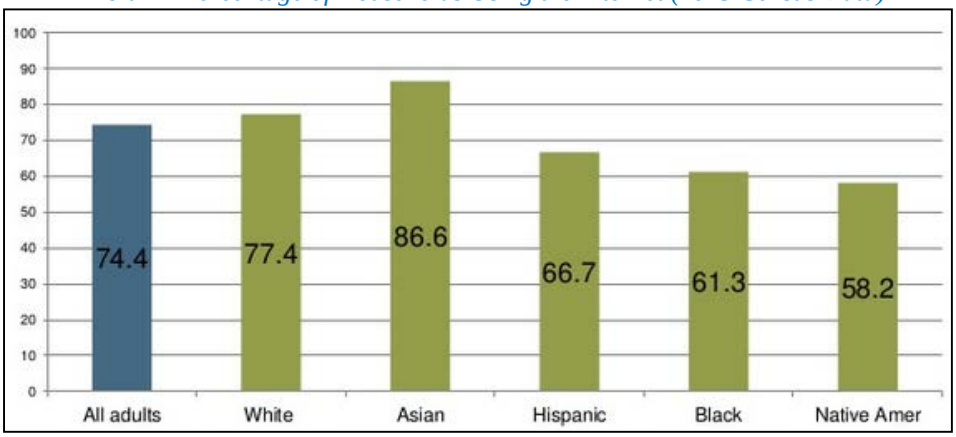
While the Internet has a profound capacity to transmit information and enable communication rapidly and cheaply, the underlying architecture of the Internet still has yet to be perfected. Researchers have looked at various segments of the population in terms of internet usage such as gender, education, Internet experience, employment status, income and residence. The United Nations Office of the High Commissioner for Human Rights summarizes it thusly:

> The term "digital divide" refers to the gap between people with effective access to digital and information technologies, in particular the Internet, and those with very limited or no access at all… In addition, digital divides also exist along wealth, gender, geographical and social lines within States. Indeed, with wealth being one of the significant factors in determining who can access information communication technologies, Internet access is likely to be concentrated among socio-economic elites, particularly in countries where Internet penetration is low. In addition, people in rural areas are often confronted with obstacles to Internet access, such as lack of technological availability, slower Internet connection, and/or higher costs. Furthermore, even where Internet connection is available, disadvantaged groups, such as persons with disabilities and persons belonging to minority

groups, often face barriers to accessing the Internet in a way that is meaningful, relevant and useful to them in their daily lives (p. 17).[7]

Within the United States, the digital divide is typically smaller than in developing countries, but it is still present and significant, as illustrated in the following graph.

Exhibit 4 – Percentage of Households Using the Internet (2013 Census Data)[8]



While this document does consider technologies that may serve to close academic performance and career interest gaps for minorities and other under-represented populations, it does not address systemic inequalities inherent to the Internet itself, as those are considered to be beyond the capacity of the DLN to address.

ORGANIZATION

The remainder of this document provides thematically grouped surveys of the literature in the following areas:

- Gaming
- Social Media
- Synchronous video (i.e. videoconferencing / webconferencing)
- Asynchronous video (i.e. video sharing sites / traditional television)
- Virtual Learning Environments (i.e. Online Courses / MOOCs)
- Mobile Apps

These sections provide details about the current state of each kind of technology. After these informative sections, there is a concluding section that provides recommendations based upon the available literature.

GAMING

While games are generally considered meaningless entertainment, there exists a powerful legacy of successful collaborations between games and education. Perhaps no single icon better embodies this symbiosis than the crimson-coated *Carmen Sandiego* – a character who first debuted in 1985

but has gone on to inspire gameshows, cartoons and comic books that all teach social studies. Moreover, *Carmen Sandiego* demonstrates clearly that gaming is broader than just video games.

Exhibit 5 – The original video game[9]

Exhibit 6 – A subsequent gameshow[10]

The success of the *Carmen Sandiego* line has led researchers to investigate the viability of other games, such as *Global Conflicts*, wondering whether the magic could be reproduced in an era of seemingly irredeemable games such as *Grand Theft Auto*[11]. The following vignette demonstrates the power that a well-designed educational video game has to make distant and complex concepts such as the Israeli/Palestinian conflict more immediately human and relatable:

> Jonas [a student] is confused about how to move forward in [Global Conflicts] to complete the mission [to interview non-player characters (NPCs) in order to write a news article]. He has not yet understood that the different NPCs to whom he talks during game play are representatives of the different sides of the conflict, and that the article that he is going to write has to contain both perspectives. With a little help from the teacher, Jonas' participation changes. By being enabled to reflect upon the relationship between the Israeli soldiers and the Palestinian prisoner, Jonas understands that what is being said by the different NPCs belongs to different voices of the conflict, and he gains insight into the multivoicedness [sic] of it. He realizes that both sides of the conflict must be reflected in the article (p. 73)[12].

However, games are useful beyond the middle school social studies classroom; within STEM, two early games were Rocky's Boots (electronics) and Number Munchers (arithmetic).

Exhibit 7 - Rocky's Boots[13]

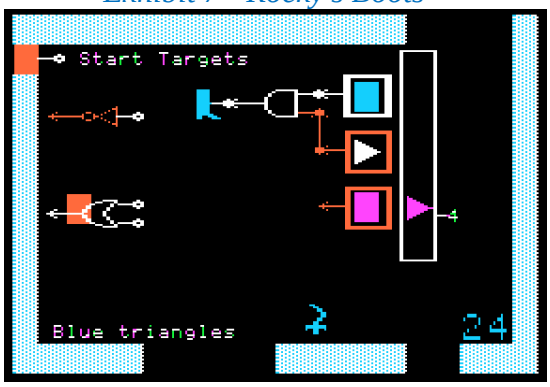


Exhibit 8 - Number Munchers[14]

Researchers have argued for the inclusion of gaming even at the collegiate level for soon-to-be pharmacists[15]. In fact, there is a wealth of research indicating how games can support a classroom aligned to the Common Core State Standards (CCSS). Appendix A provides a crosswalk of how such research ties specific features of games to educational best practices mandated by the CCSS. Games come in a variety of formats, from the ancient board games of chess and mancala through the television gameshow and into the modern video game. However, these are merely media through which the games are played. To use music as a metaphor, these are the vinyl records, the compact discs and the digital music players of gaming. Similarly, just as music has genres such as jazz and rock, games also come in a wide variety of genres, as illustrated in the table below:

Exhibit 9 - Description of gaming genres[16]

Genre	*Description*
Adventure	Player must complete puzzles or tasks by interacting with characters in a scenario. Emphasises exploration over reflexes and confrontation.
Fighter	Player competes using some means of combat, usually one-on-one.
First-person shooter	Player takes a first-person view, centred on a weapon, such as a gun. Requires speed and fast reflexes.
Music	Player emulates music using mock instruments or body movements to represent tones.
Platformer	Specific type of action game involving jumping onto platforms to travel through a course with obstacles. Emphasises precision and fast reflexes.
Puzzle	Player solves logic puzzles or manoeuvres through mazes. Often emphasises fast reflexes.
Racing	Player drives a vehicle and competes in a race. Player usually takes on the view from the driver's seat. Emphasises speed and reflexes.
Role play	Player assumes the role of a character and explores a world, gaining new abilities along the way. Many games have a science fiction or fantasy component. Emphasises story.
Simulation	Player is involved in a realistic simulation of the world. Simulations may involve life, building or business.
Sports	Player emulates the experience of a sports game. Games involve choosing strategies for play, displaying physical skills or both.
Strategy	Player has command of units, such as an army, and seeks to defeat opponents. Can either be real-time or turn-based. Emphasises tactical planning.

Given the diversity of the above list, one might wonder what all games have in common. Research indicates that people enjoy games for three main reasons: to escape, to connect socially, and to feel a sense of control[17]. The escapist element of gaming allows gamers to forget about the stresses of real life but can also allow them to explore activities without the inherent risks of real life failure. The social aspect of gaming provides an excuse to hang out with friends but can also provide rare opportunities to interact positively with a role model or younger sibling. The table below demonstrates the overwhelming interest amongst students for multiplayer over single player.

Exhibit 10 - Student preferences for social gaming[18]

	Multiplayer	Single player	Both	Total
Total	52	9	11	72
Percentage	72%	13%	15%	100%

Perhaps most salient to the educational endeavor, control in gaming can be highlighted by the following contrasting excerpts from a case study[19]:

> Mr. and Mrs. Lee were the people… who ultimately arranged and controlled… Steve's game play during the time of this analysis (e.g., to what games Steve had access, how much time Steve was able to spend playing games, with whom Steve could game). However… because Mr. and Mrs. Lee sanctioned Steve's game play and encouraged it, Steve had a great deal of autonomy when it came to his game play and thus, was able to vastly increase his gaming expertise. (p. 890)

> Unlike at home, the locus of power at school did not reside with Steve and his peers. The students were told when to use technology, how to use technology, and what technology to use for each specific task; no choice was conferred. Additionally, the extended periods of time for practice, trial and error, and reflection that were hallmarks of Steve's gaming practices at home were completely absent from his technology practices at school…One example of this manifested itself in a well-intentioned but misguided role that teachers asked Steve to play. They told him that they knew how much he loved technology and because of that, they granted him permission to be the student who was responsible for turning on all of the computers each morning in both his classroom and the school's computer lab. Steve saw the task as a burden rather than a privilege (p. 894)

The ability to choose is one of the most attractive features in games, but schools often overlook this aspect in an effort to script curriculum that fits within the traditional model – turning an opportunity for motivation into drudgery. Research has identified several such missteps that can occur in educational gaming, including the following:

- User interface is too complex;
- Rules are unintuitive or counter-intuitive;
- Winning is possible in undesirable ways; and
- Difficulty does not scale well from new players to experienced players[20].

Upon reflection, the above list applies equally to recreational games as to the educational games that were studied. In other words, before something can be a good educational game, it must first be a good game. Advocates of educational gaming caution:

> One common misconception…is that any type of gaming tactic will automatically make learning more engaging. This, however, mistakes superficial gaming experiences for specifically-designed psychological experiences… Creating quality serious games…is not an easy or inexpensive task (p. 4)[21].

Despite such pitfalls, it is clear that, when provided with a well-developed game in the appropriate context, students do learn STEM content better with the assistance of an educational game[22]. Even commercial off-the-shelf (COTS) games can provide highly motivating opportunities for students to create detailed guides that provide deep insight into the mechanics of a game[23]. The table below is a small excerpt of a player-developed spreadsheet for *World of Warcraft (WoW)*; this table is an exploration into optimizing characters for a particular trait – here, damage-per-second (DPS).

Exhibit 11 - A player-made WoW DPS optimization chart[24]

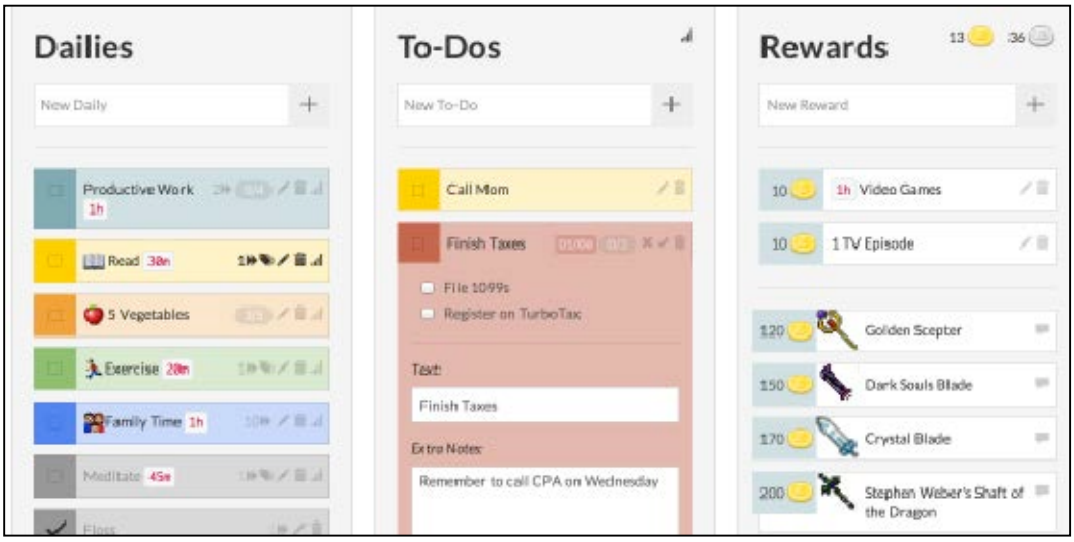
Spec	Token	0P	4P T17	2P + 2P	4P T18	2P T18
1H Frost	Vanquisher	54278	56383	56213	62372	56126
2H Frost	Vanquisher	50871	52872	52915	58572	52732
Unholy	Vanquisher	51633	54476	53610	60530	52518
Balance	Vanquisher	55672	60672	64562	64448	61537
Feral	Vanquisher	57296	61819	61704	65993	60315
Arcane	Vanquisher	63933	68396	71535	74940	69754
Fire	Vanquisher	53713	55522	57803	60243	56454
Frost	Vanquisher	62632	63564	67275	71426	66700

The above table, while just a display of seemingly random numbers to the casual observer, actually provides a detailed analysis of a variety of in-game equipment that provides a competitive edge to dedicated WoW players. Similar charts are available in just about any popular game; and, in many cases, tables like the above are produced through extensive empirical testing averaged over numerous trials. Any mathematics teacher would dearly love to be able to inspire the countless hours of statistical analysis that gamers regularly spend on creating and maintaining such charts, and that level of motivation can be captured for educational purposes. In the sub-sections that follow, several potential avenues of educational gaming are explored.

GAMIFICATION

As there are many cases in which a relevant game does not exist nor is there the time or budget to create one, there is a new trend to "gamify" aspects of everyday life by incorporating ludic (playful) elements. Appendix B contains a crosswalk of research related to various forms of gamification. Outside of education, this can be seen through the popularity of habit-tracking apps, such as HabitRPG (pictured below), which reward people for doing onerous tasks, such as chores or exercising, by giving them points or virtual currency.

Exhibit 12 - HabitRPG[25]



These rewards can be used in a variety of ways, depending on the context, that include social status, competitive rank, and so forth. One common method of gamification in education is a *token economy*, which rewards students for highly valued education acts, such as asking good questions with a tangible token (i.e. play money) that can be exchanged later for bonus points, access to field trips, or school supplies – just to name a few. Research indicates that token economies can broaden the participation[26]. However, it is possible to actually change the tenor of the classroom entirely – equating success in the classroom with success in a game.

Exhibit 13 - Gamified Classroom Elements[27]

Traditional Term	*Gamified Term*
Assignments	Quests
In-class exercises	Traditional Term
Practicum/Observations	Assignments
Final Exam	Final Boss/Boss Fight
Study Group	Guild
Individual work	Solo quest

One school has gone so far as to make gamification the central premise of the entire curriculum:

> Quest to Learn is a public Middle and High school based in New York City where students interact with in-class topics by playing and creating games. The school implements the fundamentals of gamification in the way it educates, and describes itself as "a school that uses the underlying design principles of games to create highly immersive, game-like learning experiences.[28]"

However, researchers[29] caution:

> Gamification, however, is not a simple process and can be quite complicated to implement correctly. It is not simply a matter of adding common game elements, such as points, badges, and leader boards, to existing processes or systems. Such a surface approach of gamifying existing systems translates to superficial benefits, if any (p. 233).

In other words, gamification works best when it is designed to reinforce specific behaviors or outcomes rather than simply used as window-dressing in order to disguise learning as a game. There are many kinds of gamification, which can all be equally effective, but each type can emphasize specific forms of motivation, such as:

- Leader boards – competition
- Achievement badges – skill mastery
- Progress bars – task completion[30]

Competition & Cooperation

Gamification often emphasizes social motivators for learning, which have been extensively researched. This sub-section provides a brief review of the benefits and drawbacks of competitive and cooperative learning, though these extend beyond gamification. When considering the instruction of multiple students, one of the most important decisions is whether to group them and, if so, how to do so. There are three broad categories that should be considered, as defined below:

> *Cooperative learning* is the instructional use of small groups so that students work together to maximize their own and each other's learning. It may be contrasted with *competitive learning* (students work against each other to achieve an academic goal such as a grade of "A" that only one or a few students can attain) and *individualistic learning* (students work by themselves to accomplish learning goals unrelated to those of the other students) learning (p. 87, emphasis added)[31]

Research has made it clear that either of the social learning contexts generally produce greater motivation and success than individualistic learning[32]. However, an overall meta-analysis of the research reported:

> Over 168 studies have been conducted comparing the relative efficacy of cooperative, competitive, and individualistic learning on the achievement of individuals 18 years or older. The results of these studies indicated that cooperative learning promoted higher individual achievement than did competitive (effect size = 0.49) or individualistic (effect size = 0.53) learning (p. 96) [33].

This clearly indicates that cooperative learning is the best of the three learning modes. However, this does not exclude competition entirely. *Team competitions*, which contain both cooperative and competitive elements, can be highly motivating, particularly when the top prize is highly valuable, such as an educational trip[34].

> This argument – cooperation and competition are not necessarily opposites – is strengthened further by the positive correlations between *Cooperate* and *Compete* – correlations that indeed showed that cooperation and competition are not contradictory attitudes but in fact even could be positively related. Therefore, the findings indicate that it is possible to be competitive and cooperative at the same time (p. 289)[35]

The primary concern regarding competition is the loss of self-confidence as a result of losing. Researchers have observed, "in a competitive classroom, exposure to successful models led to a decrease in participants' self-efficacy" (p. 103), but they go on to explain:

> Participants in the competitive condition underestimated their performance and those in the non-competitive condition overestimated their performance. Students in the competitive condition might have perceived their performance as failure as their work was not chosen as exemplars and consequently showed a lower self-evaluation than the raters… success of other students decreased the chance of success for observers, thus students might underestimate their own performance (pp. 103-104)[36].

These negative impacts can be mitigated by having students compete indirectly against objective performance criteria rather than directly against each other's subjective performance[37].

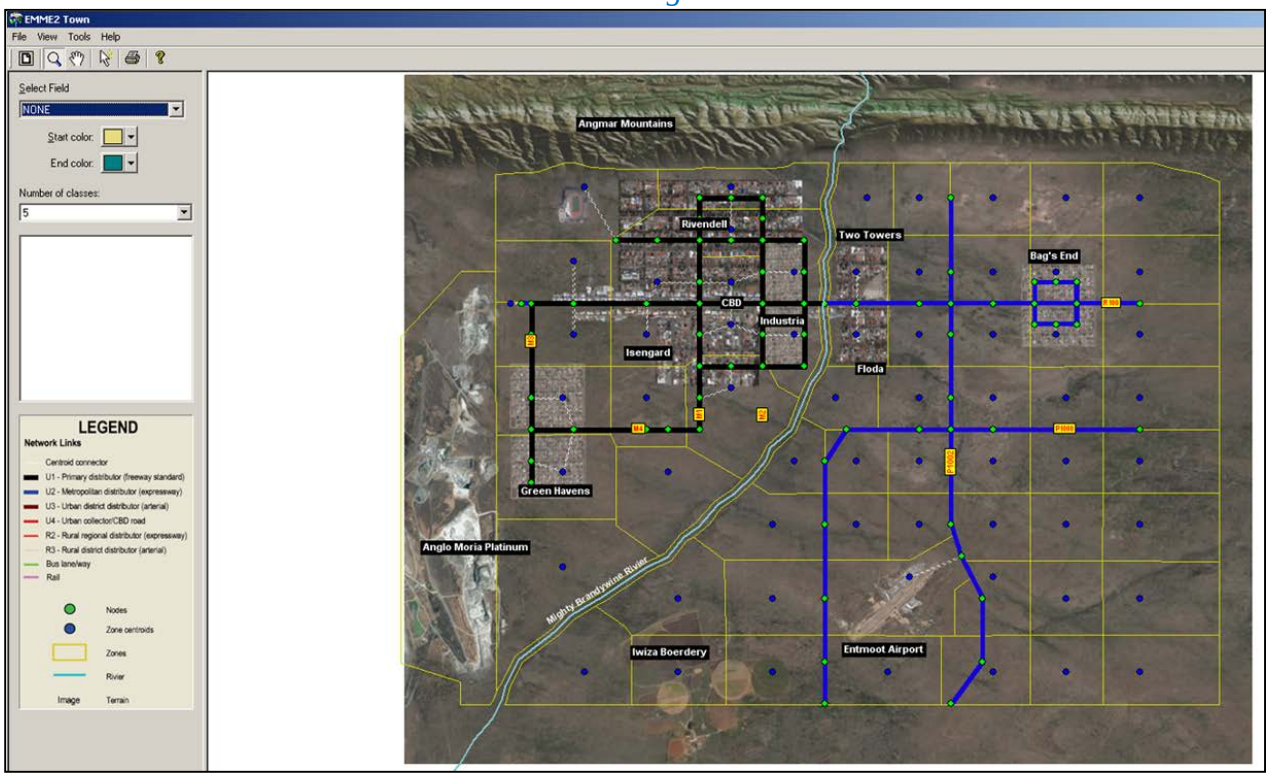
SIMULATION

Beyond the ludic (playful) elements of gamification mentioned above that can be applied to traditional classwork, actual games provide the ability to simulate scenarios outside the normal scope of the classroom. At its most rudimentary, simulation may come in the form of roleplaying – pretending to be someone else in order to understand their situation. For example:

> Students, role-playing as scientists, are asked to participate in a rescue operation to find suitable relocation sites within our solar system for six different species of aliens who have been displaced from their home planets. Through inquiry-based activities, students practice a variety of 21st century critical thinking skills such as problem-solving, self-directed decision-making, and collaboration (p. 347)[38].

Research on such roleplaying games indicates that students increase content understanding, and that performance gaps can be addressed in these ways[39]. Research has also shown that even professionals can use roleplaying to improve the efficiency of their own processes,[40] meaning that the incorporation of roleplaying in the classroom gives students important career skills beyond STEM content knowledge. However, simulation can be far more complex. This might involve technological solutions, such as in the undergraduate civil engineering simulation depicted below.

Exhibit 14 - A simulation using actual satellite data[41]



Alternatively, there may be highly structured rules, such as depicted by the table of costs from a graduate-level manufacturing simulation involving mass-production of paper airplanes:

Exhibit 15 - Costs from an industrial production simulation[42]

Type	Detail	Cost	Unit of cost
SubContractor	operator	0,8	/min
SubContractor	Technician and companion	1,6	/min
SubContractor	Engineer	2,4	/min
SubContractor	Director	7	/min
Team member	operator	1	/min
Team member	Technician and companion	2	/min
Team member	Engineer	3	/min
Team member	Director	6	/min
Team member	Expert	5	/min
Team member	Interim operator	1,5	/min
Team member	Interim technician or companion	2,5	/min
Team member	Interim Engineer	5,5	/min
Team member	Firing	12*u	Twelve times the cost unit
Raw material	A5	8	/piece
Raw material	FeuilleA4	10	/piece
Raw material	FeuilleA3	20	/piece
Raw material	pastille	5	/piece
Raw material	Texture	3	/piece
Tool	Staple	1	/piece
Tool	Scotch	3	/cm
Tool	Paste	2	/per point or cm
Tool	Cisor	2	/cut
Tool	Stapler	5	/use
Tool	Pen	2	/operation
Tool	Operating (cut, fold) ruler	1	/use
Tool	Measure Ruler	2	/measure
Tool	Photocopy	10	/use
Tool	Handling machine	1	/m
Facilities	Floor	2	/(m^2*min)
Facilities	Environment	2	/[(table, chair, desk…)*min]

The above table was utilized by students to compare their paper airplane production processes – demonstrating that the cheapest short-term solution may be more expensive when scaled up. While they could never have actually produced a million paper airplanes, the simulation game provided a way to see what would happen anyway. The sub-sections below examine specific kinds of simulations.

Virtual Worlds & Virtual Reality

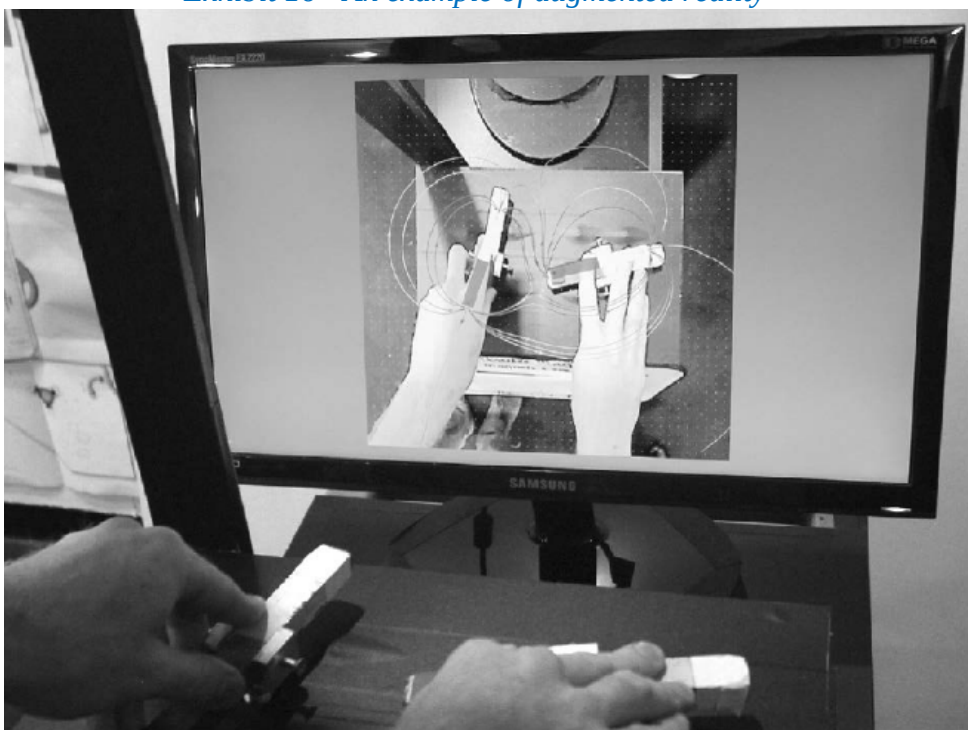
The phrase "virtual reality" likely evokes memories of the stylized and often surreal depictions in movies such as *The Lawnmower Man*. While new technologies are beginning to emerge that allow for such immersive experiences, historically the virtual worlds that people have experienced live on the far side of a computer screen. In fact, the earliest forms of virtual reality were text-based. See Appendix C for more information regarding the history of virtual worlds. The overwhelming majority of COTS video games are, to some extent, a virtual world in which the player interactions with a fictional reality through one or more perspectives. Perhaps the most widely-researched

virtual world is Second Life, which is an open-ended or "sandbox" game where players are enabled to do anything that the game engine allows, often creating new content within the virtual world. The versatility of a sandbox game makes it an easy candidate for educational research, as content can be created for essentially any academic topic. As one example, researchers noted the usefulness of Second Life in teaching about the properties of cotton[43]. Unfortunately, Second Life, as an early pioneer in its class, is notoriously plagued with difficulties – notably the 2006 interview with Anshe Chung that was "griefed" with sexually-explicit content[44]. Fortunately, other virtual worlds have become available in the intervening decade. See Appendix D for a comparison of Second Life with OpenSim, a very similar alternative, for example. Specifically, NASA has already seen the value of such sandbox games, partnering with Kerbal Space Program to create a virtual parallel to the real world Asteroid Redirect Mission[45]. Minecraft is another sandbox virtual world that has received the attention of researchers[46]. Overall, results regarding virtual worlds are sparse and slightly mixed. A study of virtual reality in chemistry failed to show improvement in chemistry content knowledge, but did improve the spatial reasoning abilities of some low-performing students[47]. In other words, virtual worlds show promise for educational value, but strong best practices have yet to emerge.

Augmented Reality

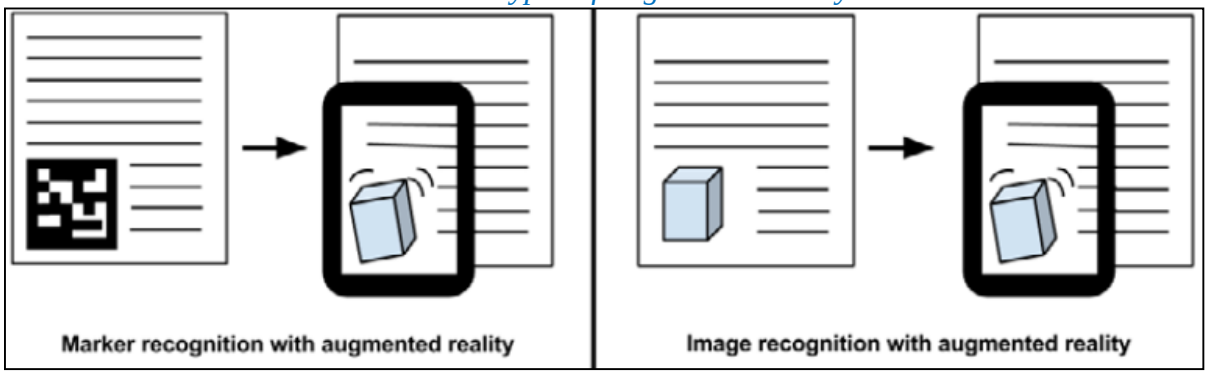
While virtual worlds creates an entirely new reality in a digital space, technology now allows us to augment the real world with data or interactivity that would otherwise be impossible. For example, augmented reality can show magnetic field lines that are invisible to the naked eye.

Exhibit 16 - An example of augmented reality[48]



Augmented reality comes in a variety of forms, but is most commonly seen in the marker-recognition and image-recognition varieties.

Exhibit 17 - Types of Augmented Reality[49]



A recent review of the literature[50] provides the following summary of the current research in educational uses of augmented reality:

- The number of published studies about AR in education has progressively increased year by year specially during the last 4 years.
- Science and Humanities & Arts are the fields of education where AR has been applied the most. Health & welfare, Educational (teacher training) and Agriculture are the research fields that were the least explored fields.
- AR has been mostly applied in higher education settings and compulsory levels of education for motivating students. Target groups like early childhood education and Vocational educational Training (VET) are potential groups for exploring the uses of AR in the future.
- Marker-based AR is the most used type of AR. In addition location-based AR is being widely applied. This can be due to the availability of sensors in mobile devices like the accelerometer, gyroscope, digital compass and the possibility of using GPS. Marker-less AR needs some improvement in algorithms for tracking objects but the use of Microsoft Kinect is becoming more and more popular.
- The main purpose of using AR has been for explaining a topic of interest as well as providing additional information. AR educational games and AR for lab experiments are also growing fields.
- The main advantages for AR are: learning gains, motivation, interaction and collaboration.
- Limitations of AR are mainly: difficulties maintaining superimposed information, paying too much attention to virtual information and the consideration of AR as an intrusive technology.
- AR has been effective for: a better learning performance, learning motivation, student engagement and positive attitudes.
- Very few systems have considered the special needs of students in AR. Here there is a potential field for further research.
- Most of the studies have considered medium research samples (between 30 and 200 participants), and most of the studies have used mixed evaluation methods. The most popular data collection methods were questionnaires, interviews and surveys and most of the studies were cross-sectional (p. 146).

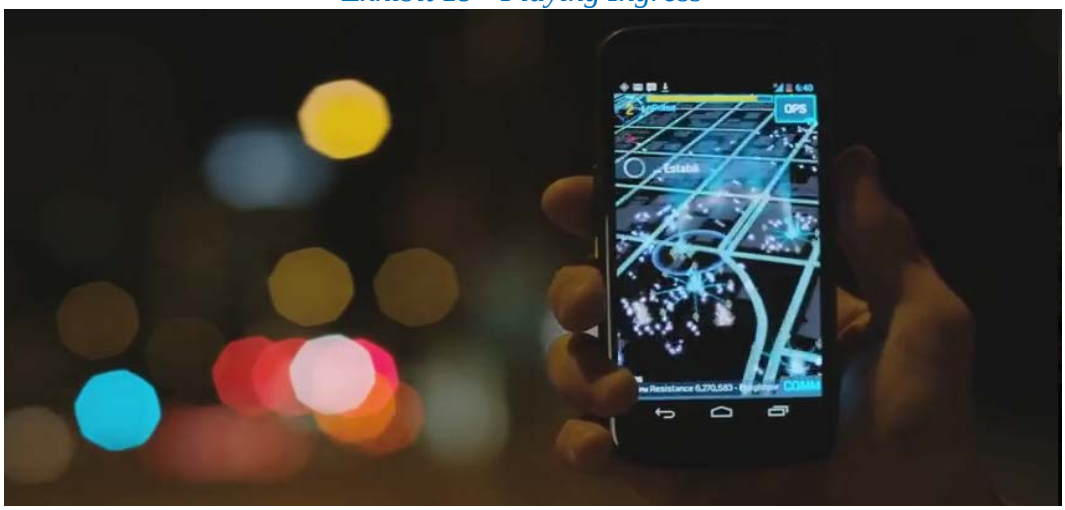
Alternate Reality

When augmented reality technology is used for gaming, the result is an alternate reality game (ARG) or, sometimes, a pervasive game. These experiences blend a combination of websites, games, viral videos, and live events in a specific form of augmented reality. These have been used in recent years to advertise movies, as seen below for The Dark Knight.

Exhibit 18 - Scenes from the Why So Serious? ARG[51]

ARGs can also stand alone, such as the territory-capturing Ingress, which integrates with actual map data using the global positioning system (GPS) and has millions of players.

Exhibit 19 - Playing Ingress[52]



While not much research yet exists, ARGs are beginning to be used for educational purposes, as seen in the example below.

Exhibit 20 - A clue from an educational ARG about nuclear proliferation[53]

It is not difficult to imagine the possibility of an ARG where players take on the role of NASA scientists and engineers, utilizing the DLN as a central hub for the action.

Motion Capture

While motion capture has been used for many years in the production of movies and video games, only in the last few years has the technology matured sufficiently to enter the classroom. COTS motion capture, particularly video game consoles, have become both relatively cheap and ubiquitous – allowing students to mimic participation in activities that might otherwise be inaccessible, as seen in the images below[54].

Exhibit 21 - Simulating weaving

Exhibit 22 - Simulating archery

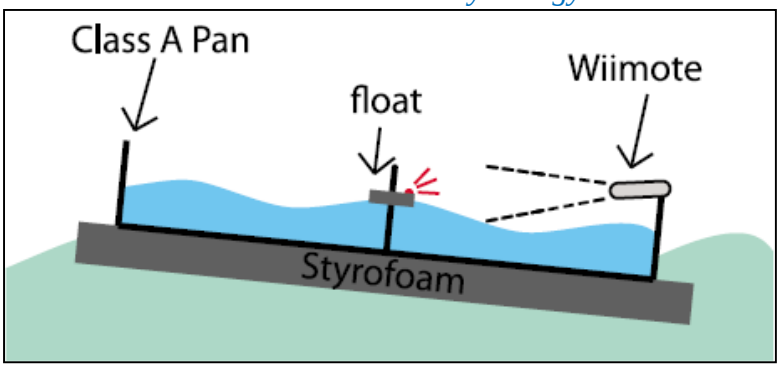
Research indicates that activities such as the above can improve understanding[55] as well as enhance long-term retention of knowledge[56]. However, it is important to remember that the gestures utilized in educational games are often highly stylized, in order to emphasize specific features or for simplicity; that is to say, these movements may not always accurately represent the real world

skill[57]. NASA has already begun to explore motion-sensing in its portfolio of educational gaming, as seen in the image below.

Exhibit 23 - NASA Mars Rover Landing for Xbox Kinect[58]

Some researchers have even suggested that COTS motion sensors, such as the "wiimote" can be used as a cheap alternative for basic scientific data collection, using setups like the one pictured below:

Exhibit 24 - Wiimote Hydrology[59]



SOCIAL MEDIA

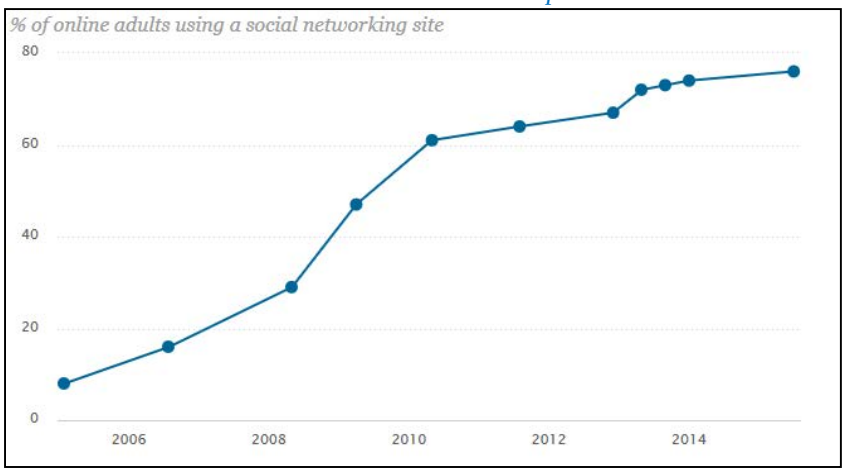
Social media refers to website and application-based tools for users to share content and participate in interpersonal networking. Content shared by users can be of essentially any variety and frequently includes text, videos, images, and audio/music. The table below provides a short enumeration of various forms of social media and their benefits.

Exhibit 25- Types of Social Media[60]

Social media tool/feature	What it is	Strengths
Audience response system	Allows audience members to become participants by responding to questions (e.g. PollEverywhere)	Interactive polling; real time feedback; engaging; generates a community standard
Blog	Online journals with entries in reverse chronological order. (e.g. WordPress, Blogger, TypePad)	Share ideas, values, reflections; improve writing skills; social tagging; generate shared vocabulary
Curation	Gathering and then sorting, categorizing, and re-sharing digital content from multiple sources to create a unique presentation of that content (e.g. Scoop.it, Storify)	Aggregating and contextualizing vast amounts of content; efficiency
Location-based networks	Allows users to share current geographical location and location history (e.g. Foursquare)	Connectedness; finding those in close proximity with whom to collaborate
Micro-blog	Character-limited blogs resulting in brief, discrete postings (e.g. Twitter, Tumblr, Posterous)	Finding and sharing information; crowd-sourcing; social tagging; instant access to large groups
Podcast	A downloadable audio or video file (e.g. iTunes)	Information delivery; easy access; can be individualized
Recommender systems	Collaborative or content filtering systems to assist individuals or sets of people to see what similar social media users like or recommend, in order to help identify useful "consensus" information in a community (e.g. used by Amazon, Netflix)	Sharing preferences; allows users to see common "likes" and "dislikes"
RSS reader	Used to manage subscriptions to online news feeds from websites which offer syndicated content. Also called "aggregator" or "feed reader." (e.g. Google Reader)	Managing information
Social network	Platform where users communicate and share information online. Users create an individual profile, engage others in their network. (e.g. Facebook, LinkedIn)	Finding and sharing information, crowd-sourcing, popularity of platforms
Wiki	Website that can be edited by multiple people simultan-eously. (e.g. Wikipedia)	Collaborative knowledge building, crowd-sourcing
Video chat	Allows for real time audio-visual communication among users at different locations. (e.g. Skype) If text only, called instant messaging.	Synchronous across different locations; allows teaching, meetings and collaboration
Virtual world	Interactive environments where real users can interact in simulated situations, often using representational avatars and in 3D. (e.g. Second Life)	Safe practice; feedback; engaging way to learn

Some of the earliest forms of Internet-based social media include bulletin board systems (BBS) via the telnet protocol, UseNet newsgroups, and website-based discussion forums. At the time of this writing, commonly used social media platforms include Twitter, Facebook, Reddit, YouTube, Vine, and Instagram. As can be seen on the scatterplot below, use of social media in all of its many forms has become nearly universal.

Exhibit 26 - Social Media Adoption[61]



Despite this upward trend, the popularity of social media platforms is not always lasting, as evidenced by deprecated sites such as Xanga, MySpace and LiveJournal. However, Facebook has, thus far, survived at least two coordinated efforts from attempted competitors Ello and Diaspora[62]. In short, social media can be unpredictable and elusive but also pervasive. Some researchers argue that the unpredictability of social media can be offset by the potential to reach far greater numbers of participants because the nature of social media is such that participants are also presenters.

Exhibit 27 - Paradigms for eLearning[63]

Paradigm	Direction	Interactivity	Media	Constraints	Outcomes
Tutoring	One to one	High	Oral (face to face)	Time, place, cost	Knowledge
Broadcast	One to many	Limited, low	Lecture, Mediated (book)	Time, place, content	Information
Engaged	Many to many	High	Hybrid (personal tutoring, online peer mentoring)	Imagination, connectivity	Creative problem solving, innovation, knowledge

Other researchers have also included peer-mentoring and collaboration in their social media strategies[64]. In other words, social media can be a "train-the-trainer" model that becomes self-perpetuating. Consequently, it is no surprise that the Trivia Challenge campaign conducted via Twitter to broaden the reach of the Science.gov received more than 60,000 "clicks" and 4,400 "followers" for the relatively low cost of roughly $6,500[65].

Research has shown that learners, both in the classroom[66] and the workplace[67], feel as if they have learned better when social media is integrated well. There is even some preliminary evidence linking participation in meaningful educational social media with academic success[68]. Despite these potential benefits, polls have indicated that 87% of K-12 teachers do not incorporate social media in their classrooms and that lack of training for interacting with students and parents through social media is the number one reported reason for not integrating[69]. Though a greater percentage of educators are using social media to engage students, there are still considerable hurdles for integrating social media into courses. Many schools ban portable technology or, at least, social media; teachers in these schools take professional risks by incorporating social media. Some teachers work around these limitations through school-specific social media platforms such as Edmodo, especially to eliminate scenarios such as the following:

> Francesca… had been Facebook friends with her female drama teacher for four years. Regularly posting information about class and rehearsals, Francesca felt the teacher's posts were helpful, but in her eyes *this teacher was just one of a thousand online friends vying for her attention* (p. 116, emphasis added)[70].

Despite such difficulties, social media does see educational use. The graphs below illustrates the results of one survey of the use of social media both in-class and as student assignments.

Exhibit 28 – In-class use of social media[71]

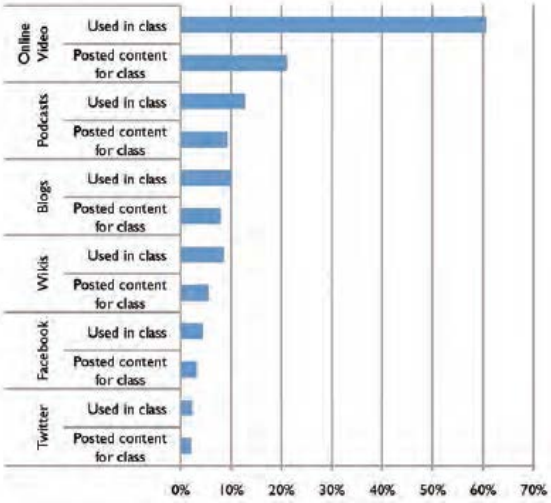
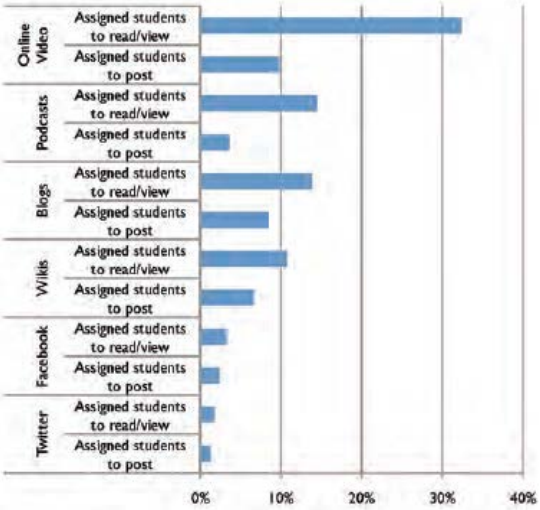


Exhibit 29 - Assignment use of social media[72]



A review of the dissertation research in social media[1] indicates that the DLN could potentially utilize social media in at least three distinct ways:

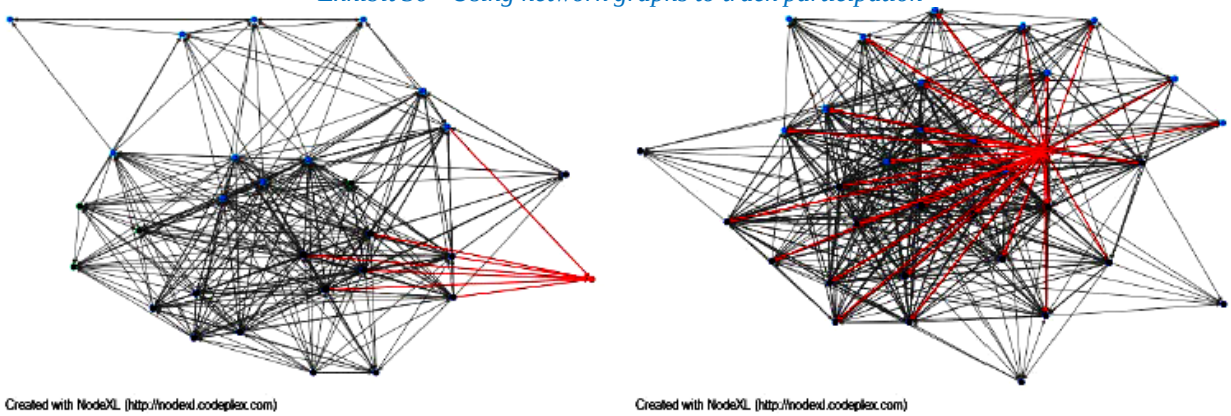
- to address large-scale issues, such as climate change;
- to increase the market penetration and network of potential partners; and
- to enhance educational outcomes directly.

Other research indicates that social media can also be used by the DLN to help make NASA and its SMEs seem more approachable[73]. However, it is important that any social media posted by the DLN be perceived as authentic.

> When participants perceived an institution's blog as authentic, they were more likely to select the institution as a good fit and were open to furthering a relationship with that institution... *sharing descriptive and personal experiences, stories, opinions, or beliefs—was by far the most prevalent contributor to the perception of authenticity*. Participants identified blogs as authentic when bloggers told descriptive stories about personal relationships, shared beliefs or concerns similar to those of participants, and disclosed feelings—especially when they were positive in nature…In the focus group, participants said they were skeptical of… bloggers who did not share opinions. *They perceived blogs that lacked disclosure as more likely to be edited or censored, and they associated them with advertising*. (pp. 338-339, emphasis added)[74].

On a large scale, tracking the success of social media can be difficult. However, on a small scale, some researchers have used egocentric network graphs that track participation of individuals, such as in the before-after images below.

Exhibit 30 - Using network graphs to track participation

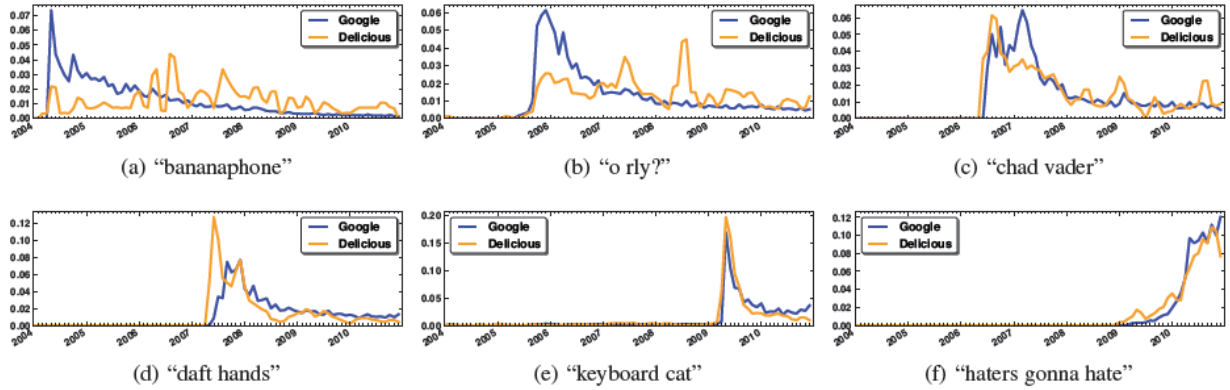


In such graphs, each point represents a person and the lines represent connections to other people. The quantity of participation is represented by closeness to center as well as number of connections. In the above exhibit, one participant is highlighted in red – showing a dramatic increase from before (left) to after (right).

VIRAL MEDIA

Viral media refers to videos and images that become immensely popular in a short time through internet sharing. It is described as a viral process because the information is spread exponentially to large numbers of people.

Exhibit 31 - The explosive potential of viral media[75]

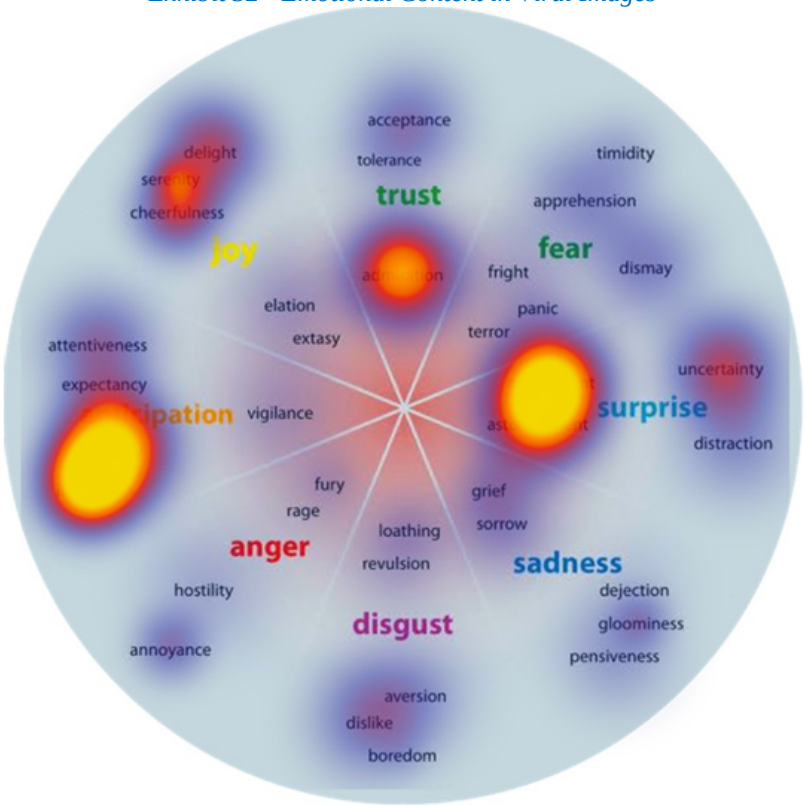


Although there are no specific parameters for what makes something "go viral," viral media is often studied in relation to marketing campaigns and branding. Studies have investigated numerous traits: title length, video length, elements of music, emotional tone, demographics of people portrayed, talent, celebrity appearances, and incorporation of violent or erotic elements. An analysis of the top twenty-five most shared viral video ads between 2006 and 2013 indicated the following:

- Nine-tenths of them have a prominent emotional theme of happiness
- Three-quarters of them used surprise (i.e. stunts, unexpected events, celebrity appearance)
- Half of them targeted an international audience, while a third targeted the USA alone.
- They averaged between two and three minutes, but there were some almost ten minutes long.

In a similar analysis[76] of 30 highly viewed images a popular image sharing service, images evoking positive emotions such as curiosity, amazement, and admiration had greater viral success. The results of this study indicate that making a positive emotional connection with the targeted audience is a common element in viral media. The heat map below is a compilation of the results.

Exhibit 32 - Emotional Content in Viral Images[77]



Such research provides evidence-based best practices in any effort by the DLN to publish social media in order to maximize viral potential.

SYNCHRONOUS VIDEO

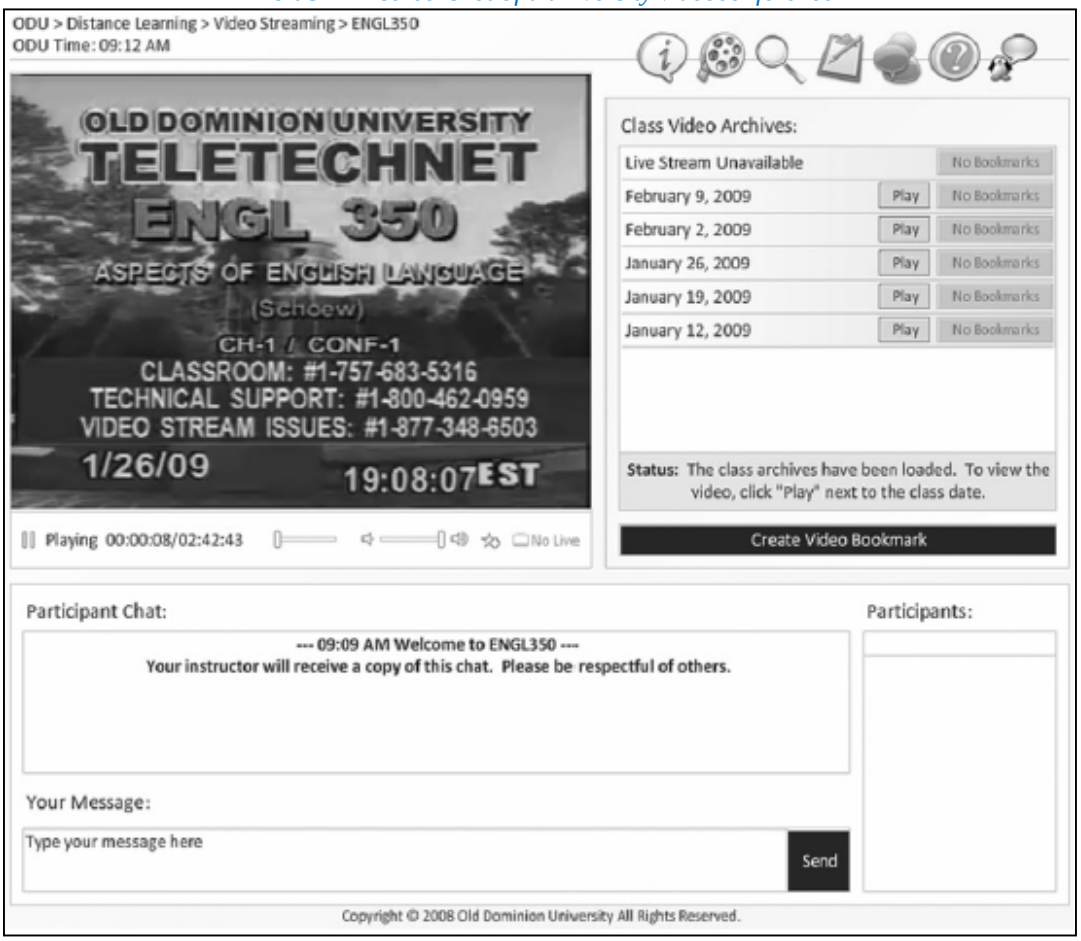
Online experiences generally fall into two categories – synchronous and asynchronous. Synchronous activities are in some way occurring in the moment or "live." Contrastingly, asynchronous experiences are always available but have been pre-recorded or otherwise archived. It should be noted that essentially anything that can be conveyed via the Internet can occur either synchronously or asynchronously, as demonstrated by the table below.

Exhibit 33 - Synchronous vs. Asynchronous

Medium	Synchronous	Asynchronous
Text	Instant messages (i.e. AOL Instant Messenger)	Email (i.e. Gmail)
Audio	Voice chat (i.e. TeamSpeak)	Podcast (i.e. SoundCloud)
Video	Videoconference (i.e. Skype)	Vlog (i.e. YouTube)

This section focuses on synchronous media, and a subsequent section will address asynchronous media. Specifically, these sections will focus on videoconferencing (including webconferencing), as most platforms that are primarily used for transmitting video are also capable of transmitting several other forms of media as seen in the screenshot below (see Appendix E for more details).

Exhibit 34 - A screenshot of a university videoconference[78]



BENEFITS

Videoconferencing has been shown to be effective year[79] after year[80]. As a result, it comes as no surprise that NASA has already begun to use videoconferencing for educational purposes[81]. However, videoconferencing is not to be confused with fully-fledged virtual learning environments, which are discussed in a later section; researchers elaborate:

> During videoconferences… students should be able to do the following: share what is on their mobile devices, share digital whiteboard functionality and share objects like those typically displayed via document camera. Although free applications like Google Hangouts and Skype allow for videoconferencing and application sharing, they do not have the classroom management features for faculty to control the communication and collaboration in and between physical classes (p. 96)[82].

In addition to simply improving learning, videoconferencing has the potential to help solve at least two serious ongoing issues with STEM career interest. First, there is transparency; one researcher described the issue as follows:

> *Because most children experience limited contact with real scientists*, the main source of their images of scientists and what it means to do science is often the media, including, for example, television, videos, books and magazines. Since the majority of the images in popular media are stereotypic, *children need access to resources that promote diverse images of who can do science, the kind of work that scientists do and the environments where scientists work* (p. 330, emphasis added)[83].

The second issue is one of identity. Researchers regularly describe how easily, for example, women can come to believe that there is not a viable identity to be found within STEM careers, as highlighted in the following two excerpts:

> Students see who succeeds in a given field and what it takes for them to do so… [but] Nadine literally could not see a female surgeon. Consequently, she felt like an outsider, unable to see a space in which she could belong [as a surgeon] (p. 550).[84]

> I said [to my daughter] so how do you feel about science? And she said it's really interesting, I love it, but don't only geeks do it? … because she's got this impression that only people who don't have a life do science, which is terrible… I have to blame TV … and they just sit at the computer or they do something and they don't have a life. They're like geeks. (p. 180).[85]

The DLN, then, should seek to use videoconferencing to highlight both individuals who represent the diversity of NASA's workforce as well as to demystify the process of science.

TRAINING

It should be noted that the research literature indicates that not every use of videoconferencing is a success. While some researchers described videoconferencing as "comparable or better than face-to-face" (p.5)[86], others note that students are less satisfied with videoconferencing than face-to-face[87]. These mixed results have caused researchers to investigate the underlying causes of success or failure with videoconferencing. Foremost among the variables is that both participants and instructors perceive use of videoconferencing to be easy; being perceived useful and motivating are also significant[88] (see Appendix F for more details). The following participant survey response illustrates this nicely:

> Google Hangouts can be a great tool but I have found it very hard to use and it was not easy for me to learn how to use… I just wish Google Hangouts was easier to use or I received more training in how to use Google Hangouts (p. 32)[89].

As a result, the following recommendations, while worded for a university context, are a typical representation of the literature regarding best practices in video conferencing.

- University **Training Opportunities** for all instructors: More training must be developed by the university and secured by each instructor to understand the technology of videoconferencing. Without this knowledge students will continue to perceive the discomfort of the instructor and ultimately develop a general bias to technology during their first introduction to this medium for instruction.
- **Investment in Equipment**: More funds need to be invested in the updating and the maintenance of videoconferencing equipment. In order to keep up with the needs of the 21st century learner, a budget that focuses on the improvement of equipment/hardware must be a part of the university's priorities and budget.
- **Onsite Support**: Non-traditional college students who are interested in or qualify for teaching assistants should be trained to moderate and support the given technology. This would help the university to use its present financial resources in a manner that allows technologically savvy students or tutors to manage the equipment during course sessions.
- Full Time **Faculty Workshops**: A session on the pedagogy of using real time video technology needs to be instituted within the training days of the university for faculty. Such a workshop would help instructors understand how to work with people at remote sites in an appropriate manner (p. 401, emphasis added)[90]

In order for the technology to be easy to use, the DLN needs to provide training and support as well as have contemporary equipment and software. Together, these will provide the end user with a similar level of ease to which they have become accustomed with, say, their smart phones. Training needs to occur both for educators as well as the NASA SMEs with whom they will collaborate – particularly in the basic use of the videoconferencing hardware or software. For the SME, some additional training topics identified by research include:

- Good questioning skills
- Explaining academic content
- Dealing with unexpected student questions
- Hands-on / Inquiry-based / Problem-based learning
- Establishing rapport with students
- Avoiding excessive lecturing[91]

For the educator, research has identified other topics of training, including:

- Explaining how SME information is relevant to classroom content, especially assessments and tests
- Encouraging students to participate and not feel intimidated by the SME
- How to convey academic needs to SMEs[92]

EVALUATION

The chart below is an example of a rubric taken from the peer-reviewed literature that could be easily adapted to the DLN's needs.

Exhibit 35 - Videoconferencing Quality Rubric[93]

Category	Description	Measurement			
		3	2	1	0
Learning Objective	Specific statements of learner outcome from the global project	All learning objectives were accomplished or exceeded.	Most learning objectives were accomplished.	Some learning objectives were accomplished.	No learning objectives were accomplished.
Student Interaction	The level of communication between students and partner schools.	Students developed one-to-one communication, group communication, or class communication on content-related topics. Students experienced new friendships with their partner school.	Students developed group communication and class communication on content-related topics.	Student interaction included introductions and superficial conversation.	No face-to-face student interaction took place in the project.
Cultural Diversity	The exploration and recognition of cultural identity of students in their partner schools.	Cultural diversity was experienced through discussion and demonstration.	Cultural diversity was verbally discussed between schools in a video conference.	Cultural diversity was exchanged in written form.	No cultural diversity was shared.
Communication Tools	The technology tools used to effectively communicate between schools.	Communication tools (e.g., Skype, video conferencing, websites, email, wikis, and blogs) were appropriate for age of learners. Tools facilitated a high level of interaction between students.	Communication tools were age appropriate, but only facilitated a minimal level of interaction among students.	Communication tools were not appropriate for age of learners and did not facilitate interaction among students.	No communication tools were used or communication was not exchanged.
Effectiveness of Technology	The reliability and performace of the technology tools used during partner collaborations.	Technology tools were seamless and facilitated learning.	Technology tools worked effectively with few glitches.	Technology tools continually cut out during learning sessions.	No technology tools were used or technology tools did not perform.

Even if not used for formal evaluation, it would be important for the DLN to highlight the best practices identified by this rubric in the training of faculty and SMEs prior to implementation. Likewise, Appendix G contains a variety of possible survey items for evaluating success of activities involving videoconferencing.

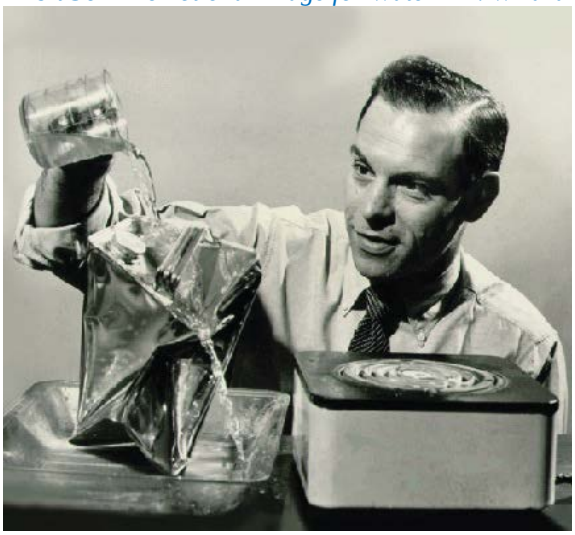
ASYNCHRONOUS VIDEO

It should be noted that research indicates that synchronous media outperforms asynchronous media both in terms of interactivity as well as academic success[94]. Unfortunately, synchronous media is by its very nature fleeting. Asynchronous ("archived") media provides an opportunity to preserve some of the benefits of synchronous media but available indefinitely. Additionally, by producing media in advance, rather than in the moment, asynchronous media provides the opportunity for content producers to develop highly polished products over the course of multiple recordings. A research survey confirmed that:

> Written survey responses from students supported assertions that the videos helped to keep students' attention, generated interest in science, and clarified understanding. Students cited the benefit of visual learning along with the lecture in helping them understand scientific processes and principles. Video provided students with memory cues and connections that also helped them remember conceptual ideas. Students preferred shorter video segments of higher quality that were specifically content related. (p. 26)[95]

As in the preceding section, this section will focus primarily on video, as it performs as well as[96] or better[97] than other forms of asynchronous media in terms of student outcomes. Of course, traditional television represents the most successful form of asynchronous video to date. While some episodes are broadcast live, contemporary television is predominantly asynchronous. From its inception, the medium has been used both to entertain and to inform including nightly news, cooking shows, and variety shows. As the medium proliferated, educational content was explored, including the iconic *Watch Mr. Wizard* (right). However, many programs were compromised by the commercial funding structure, leading one historian to opine:

Exhibit 36 - Promotional image for Watch Mr. Wizard[98]



> With the level of viewership providing an essential element for the commercial broadcast of science related television programming, the limited number of any educational programs—let alone science related television programs—on network television has virtually excluded network-derived programming from having an influence on science teaching. (p. 231)[99]

There were a few notable exceptions such as *The Bell Laboratory Science Series*, but these were done as specials and not regular broadcasts. The rise of public television provided an opportunity to present science programming less dependent on viewership including such notable shows as *The Ascent of Man*, *Bill Nye the Science Guy*, and *NOVA*. Public assets provided funding to produce quality programming. With the rise of cable television, another avenue of educational program became available and cable networks such as Nickelodeon and The Discovery Channel not only created programming but made it available during the school day along with lesson plans and other support materials. For educators, the use of these resources became practical with the advent of video recording:

> The flexibility of usage … allowed the videotaped motion picture to attain a position of preeminence in classroom practice. Not only was it a simple matter to use teacher-created videotapes, but the ability to bring recorded television images into the classroom eliminated the constraints imposed by inconvenient broadcast times (p. 241)[100]

Today, much of this media is moving online via video sharing or hosting services. Some researchers have gone as far as to assert, "Modern teaching processes are based on the use of multimedia teaching materials and the Internet (p.277).[101]" These online repositories allow a greater amount of freedom for teachers to choose educational videos on-demand to share with their students. A host of new companies are currently sharing and storing content on-line such as Vevo, Hulu, and most notably YouTube. Educational content has seen a huge growth in programming

and content distribution on these sites as well. Complex subjects are now being explained by subject matter experts (individuals), professional organizations, and educational institutions from locations around the globe, including NASA, Kahn Academy, MIT, Discovery Channel, PBS, and Scientific American.

Exhibit 37 - Screenshots of educational YouTube channels

The potential benefits of asynchronous video are numerous, as indicated in the list below:

Exhibit 38 - Possible benefits of video clips[102]

1. Grab students' attention;	11. Foster creativity;
2. Focus students' concentration;	12. Stimulate the flow of ideas;
3. Generate interest in class;	13. Foster deeper learning;
4. Create a sense of anticipation;	14. Provide an opportunity for freedom of expression;
5. Energize or relax students for learning exercise;	15. Serve as a vehicle for collaboration;
6. Draw on students' imagination;	16. Inspire and motivate students;
7. Improve attitudes toward content and learning;	17. Make learning fun;
8. Build a connection with other students and instructor;	18. Set an appropriate mood or tone;
9. Increase memory of content;	19. Decrease anxiety and tension on scary topics; and
10. Increase understanding;	20. Create memorable visual images (p. 2).

Of particular interest, the use of asynchronous video is helpful in increasing motivation[103] and participation[104] of low performing students. Research indicates that "'Attractive' videos result in better learning outcomes…the main quality of the 'attractive' video segments was the rich and useful amount of transferred information and knowledge (p. 273)[105]." In other words, for asynchronous video to be effective, it must:

- **Give context and align purpose**: The content of the video and its intended purpose should be clearly signposted to maximise [sic] the likelihood of viewing, and to ensure maximum comprehension and meaning-making through the learning experience
- **Tell (show!) a story**: This often starts with teasing out the teachers' own narratives, experiences and stories that are relevant to the content
- **Present with authenticity:** it must seem like the teacher is speaking to an individual student personally and directly – almost like a one on one conversation
- **Keep it short and to the point**: the most important concepts should be presented first if possible. Where there is need to convey a number of concepts, we try to structure that content around a number of shorter videos rather than one longer video (pp. 73-75)[106].

Research also shows that it is better for these videos to be explicitly educational than entertaining, and for the video to be used in the middle of lessons to break up lecture rather than at the beginning or end of the lesson[107]. However, use during lecture is not the only successful incorporation of asynchronous video that research has identified. The so-called "flipped" classroom involves students watching video clips at home either as a supplement or a replacement for classroom lecture; this supposedly allows for more in-class time to be spent on guided practice where the teacher can provide troubleshooting when students get stuck. Students opine that a "flipped" classroom requires greater active participation, is a better use of instructional time, allows for a greater diversity of learning experiences, but the "flipped" classroom does not necessarily improve student performance[108]. Rather, the promising practice seems to be a middle ground between the two extremes rather than an entirely "flipped" classroom, as described by the following student quotes:

- Because of the videos [watched at home], doing homework and studying in generally were remarkably easier. In addition, the videos helped to [review] the content before exam as taught by the teacher
- The repeatability of videos was a good thing. I was able to watch the videos as many times as I needed or to pause the video to take time to internalize and understand. (p. 76)
- The videos are very good additional resource. They can't replace the contact hours [with the teacher]. (pp. 75-77)[109]

The relative importance of asynchronous videos compared to other educational elements, as ranked by students, is summarized in the table below:

Exhibit 39 - Learning methods ranked by students[110]

Rank	Learning method
1	Contact teaching
2	Exercises during lectures
3	Watching short videos
4	Doing homework on my own time
5	Reading theory on my own time

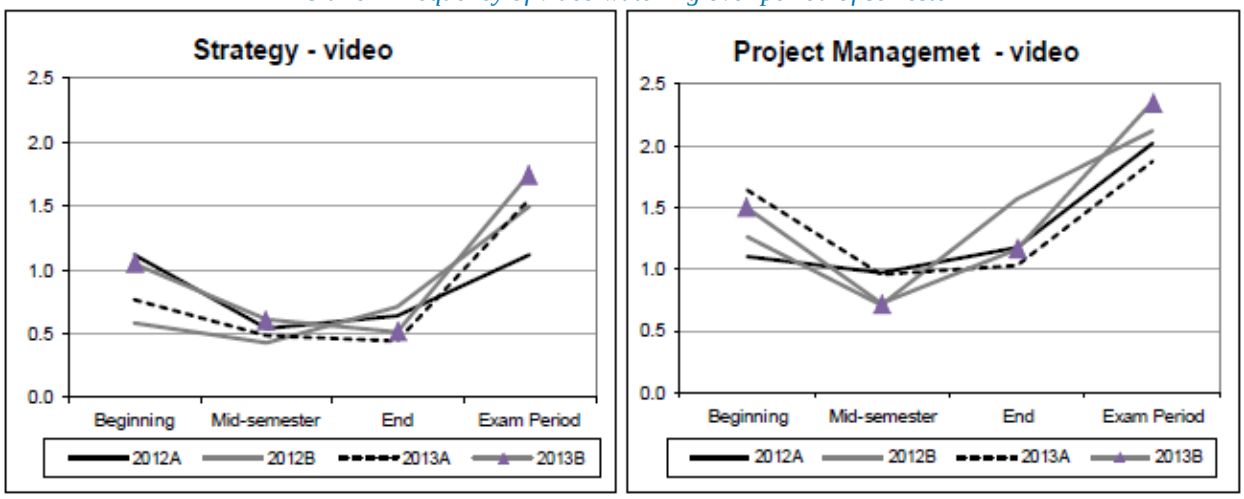
VIRTUAL LEARNING ENVIRONMENTS

In the above sections, various forms of content delivery were discussed. However, content itself is often useless without a user-friendly platform through which it can be published. Herein, Paragon TEC refers to such platforms as *virtual learning environments* (VLE). While the term is sometimes used interchangeably with *virtual worlds*, as described in an earlier section, it is herein used synonymously with *course management systems* (CMS) or *learning management systems* (LMS). In general, a VLE provides the following functionality:

- centralize and automate administration [of a course or lesson]
- use self-service and self-guided services
- assemble and deliver learning content rapidly
- consolidate training initiatives on a scalable web-based platform
- support portability and standards
- personalize content and enable knowledge reuse (p. 1)[111].

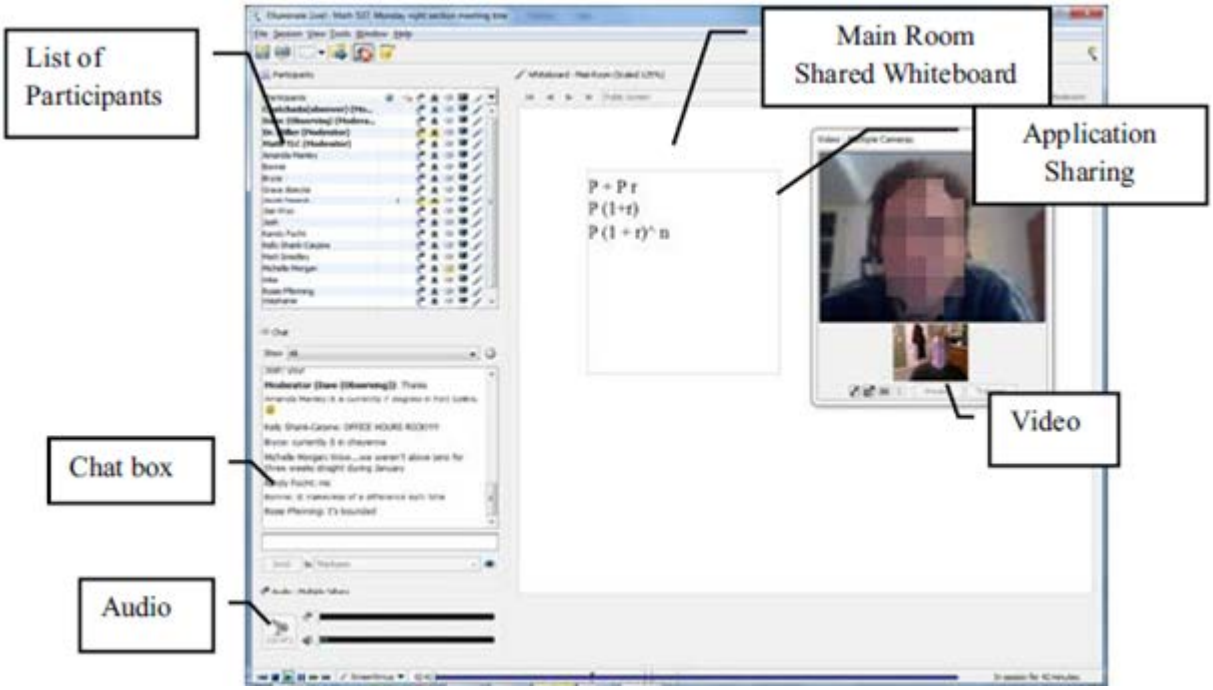
The final feature, knowledge reuse, is demonstrated in the scatterplots below, which show video use by students both at the beginning (to learn content) and end (to review content) of a given semester.

Exhibit 40 - Frequency of video watching over period of semester[112]



Common VLEs include Moodle, Blackboard, EdX, and Udacity, and they typically have a combination of synchronous and asynchronous components.

Exhibit 41 - A screenshot of Elluminate Live! in use[113]



It is important to note that simply placing content online does not automatically make it a successful course; researchers have noted that there is:

> such a high degree of common-sense similarity between most of the design and structural elements of face-to-face tuition and asynchronous tuition that our conclusion was to defer to the existing literature on optimal design and structure (p. 6)[114].

That is not to say, however, that face-to-face and online courses are interchangeable. A review of the literature[115] has identified numerous factors which can influence a student's satisfaction with online courses, many of which would not apply to a face-to-face course, including:

- Whether users have a sense of self-efficacy in using the VLE
- Whether users have positive attitude regarding technology, generally
- Whether users have anxiety when required to use technology, generally
- Whether training is available to users about how to use the VLE
- Whether the organizational management supports the VLE
- Whether technical support is available for the VLE
- Whether users consider the VLE to be useful
- Whether the VLE is easy to use
- Whether the VLE can be accessed "anytime anywhere"
- Whether the VLE allows for interaction, rather than simple passive participation.

In fact, a survey indicated that many teachers lack awareness of VLEs; those who know of VLEs have intense concerns with respect to logistical issues such as time investment[116]. In implementing a VLE, researchers[117] found that:

> Participants described teaching in a virtual classroom as an "intense" or "demanding" experience requiring concentration or focus (p. 264).
>
> They described the need for strategies to manage interactions, for example, to bring people into discussions, to ensure everyone is heard, for interrupting those who "hog the floor," for handling silences and for managing small group work, which were different from their face-to-face practice. There is evidence that some facilitators found giving learners responsibility and adopting learner-centred strategies challenging in the absence of visual feedback (p. 268).

Given such results, the following evidence-based promising practices are not surprising:

1. Provide support for the instructors and students and provide access to [VLEs]
2. Conduct workshops demonstrating the ease of use and set up of [VLEs]
3. Have faculty experts on [VLE] technology present/conduct workshops on the use of [VLEs].
4. Advertise to the faculty how [VLEs] can contribute to personal factors such as reducing travel time/cost, improving teaching, and enhancing student learning.
5. Have peer support groups available for faculty. This can include separate groups by gender, since female faculty rated personal factors much higher than male faculty (p. 202)[118]

These indicate that, if NASA wishes to pursue VLEs, that the DLN could enhances success by conducting train-the-trainer workshops as well as providing ongoing support.

EVALUATING VLES

Selecting a VLE requires specifying organizational priorities. For example, Moodle is a popular choice because it is open-source and, consequently, low-to-no cost[119]. However, there exist numerous peer-reviewed measures than can evaluate a specific VLE on one or more dimensions. For example, the widely used System Usability Scale (SUS)[120], has been validated for use in evaluating how easy it is to use a given VLE[121]. Other researchers[122] have reported utilizing the following instruments for measuring the social aspects of a VLE:

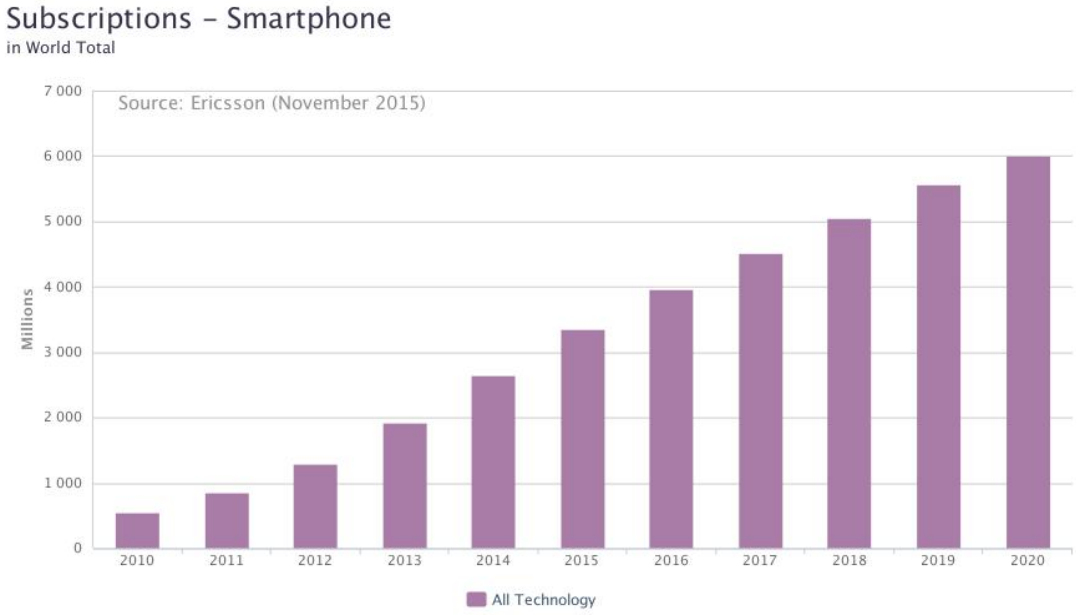
- Kreijns, Kirschner, Jochems, and Burren's (2004) Sociability Scale, Social Presence Scale, and Social Space Scale
- Rovai's (2002) Teaching Presence Scale

In this way, given particular goals and objectives, it is likely that an appropriate metric exists to serve as an objective comparison between different VLEs. If, alternatively, an evaluator wishes to document how a particular VLE is being used, researchers have utilized access logs both to determine how much or how often a particular page is viewed as well as how users navigate between pages within the VLE[123].

MOBILE APPS

For decades cell phones have increasingly been used as personal companions to aid communication, but the turn of the 21st Century was marked by the advent of personal digital assistants (PDAs) and, shortly thereafter, the smartphone. Popularized as a result of the births of the iPhone in 2007 and Android in 2008, there are enough smartphones in use today to account for nearly half the human population worldwide.

Exhibit 42 - The Smartphone Explosion[124]



In the United States, smartphone use is even higher, particular among the youngest citizens.

Exhibit 43 - Rise of Smartphones in the USA[125]

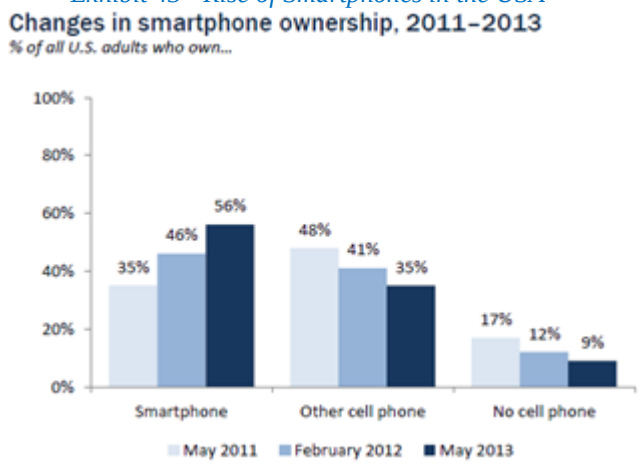
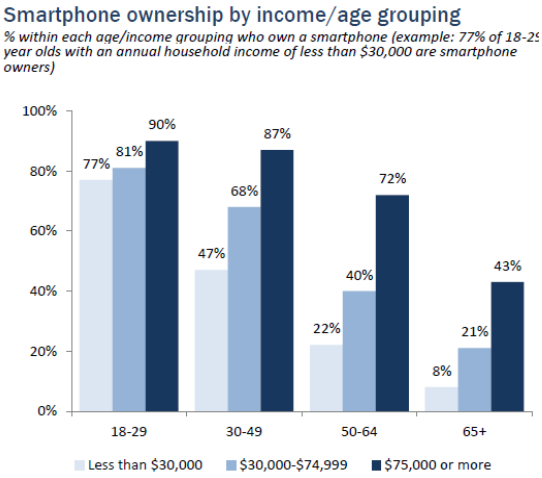


Exhibit 44 - Youth and Smartphones[126]



With such rapidly accelerating growth, it would be utterly irresponsible for the DLN to ignore the mobile sector. In the above sections, the cited research was overwhelmingly conducted with desktop computers and laptops. While laptops offered some mobility, both categories of devices are largely stationary, have large screen sizes (13" minimally for laptops, and 19" minimally for

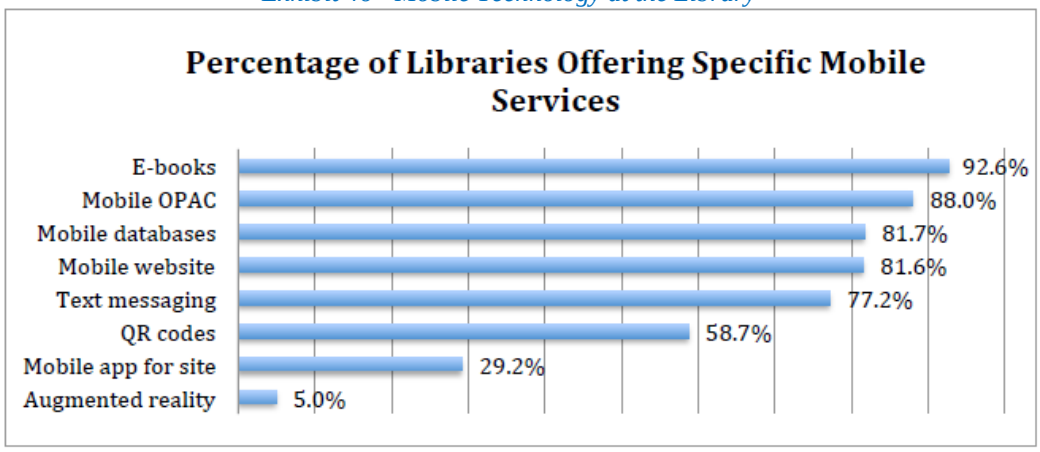
desktops), and are operated with a keyboard and mouse. In contrast, smartphones and tablets are highly portable, have small screen sizes (4-6" for smartphones, 7-13" for tablets), and are primarily operated with a touchscreen and some limited voice commands. These differences lead to the question: what is the role of these mobile devices in improving STEM education for students?

Certainly, smartphones and, recently, tablets have access to thousands of software applications ("apps") between the two most common operating systems – iOS and Android. Many of the software applications that originally launched for desktop have direct mobile equivalents. For example, Minecraft was mentioned in the gaming section above, and it is available on both iOS and Android as Minecraft Pocket Edition. Similar mobile editions can be easily found in every category of software mentioned; even virtual reality is available to mobile thanks to projects such as Google Cardboard that rely on a smartphone to do most of the work.

Exhibit 45 - A promotional image for Google Cardboard[127]

In general, the use of digital technologies in the classroom allows teachers to take advantage of students' interest and willingness to use technology, to assess the benefits of learning through an array of devices[128]. Additionally, thanks to the relatively low cost of mobile learning technologies, districts can more easily access these types of tools to provide digital equity among students[129], even helping to close the achievement gap for struggling students[130]. Recognizing this, NASA has already made numerous apps available[131]. Mobile technology has the potential to do more than simply make digital expansion more portable. Totally new avenues are growing. The following graph shows how university libraries nationwide have begun to incorporate mobile:

Exhibit 46 - Mobile Technology at the Library[132]



In addition to the obvious use of digital expansion for e-books, libraries have begun experimenting with responding to inquiries via text message and conveying information through QR codes – both avenues entirely unique to mobile. Similarly, an app has been developed that enables photo documentation of a lesson observation in order to help pre-service and in-service teachers improve their pedagogy.

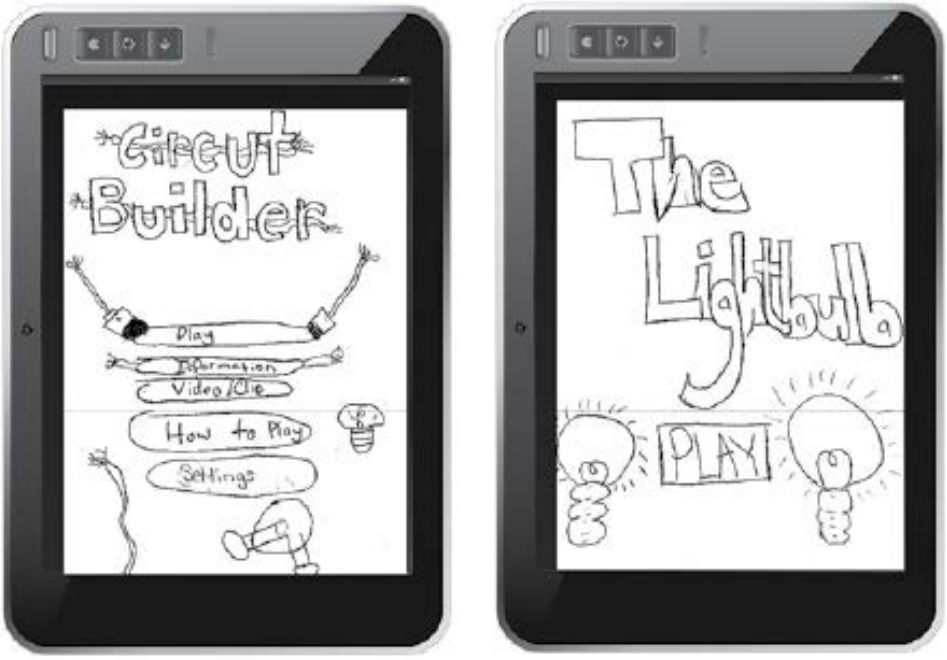
Exhibit 47 – Screenshot of the Common Core Look-fors app[133]

However, a recent systematic review of the literature on mobile devices has made it clear that the instructional use of mobile technology is still in the earliest stages of refinement[134]. A major concern is that the apparent success of mobile may be more due to novelty than inherent benefit. One teacher described the issue as follows:

> It's really just to get the kids involved, they like using them….The students were lot more excited about the material. They were really into it. They really wanted to use the iPads, because most of them have not had the opportunity to handle the iPad, so their enthusiasm was through the roof when we started using them (p. 40)[135]

This entertainment-seeking is further substantiated as a confounding factor by a study that asked elementary students to come up with the basic idea for a mobile app to help learn about electricity; all 89 students designed mobile games rather than other forms of app, such as tools or utilities[136].

Exhibit 48 - Students think of apps as games[137]



RECOMMENDATIONS

The preceding sections provided contextual information regarding the current state of several technologies that are emerging as new avenues of instructional technology. In this concluding section, recommendations are provided. Overall, it is clear that NASA should be investing its resources in educational technology, and the recommendations below help provide greater clarity about those investments should occur.

CROSS-CUTTING

Recommendation 1: NASA should consider ease-of-use as paramount in selecting technology

Regardless of the type of technology addressed, the research literature is overflowing with examples of how the relative ease or difficulty of a particular technology can make or break any instructional use. Ease can be quantified in a variety of ways (e.g. number of clicks to accomplish basic tasks) but may be better captured through qualitative assessment (e.g. whether people actually feel as if it is easy to use) such as through pilot testing. After all, even the best educational content will be missed if users quit using the technology due to frustration. In selecting any educational technology, NASA should consider ease-of-use to be the primary differentiator between competing technologies.

Recommendation 2: NASA should consider social interactivity in selecting technology

Across all technologies, participants identified one of the prime benefits of digital expansion is the ability to connect socially – whether with students, peers, or mentors. Even in the case of

asynchronous video, where information can only flow one direction, participants remarked on the appeal of the seemingly closer connection with presenters via pre-recorded video as opposed to via email or other texts.

Recommendation 3: NASA should first consider off-the-shelf technology solutions

In every category, products were already available that might be adapted to NASA's educational needs. Development of any of these products tends to be long and costly, and there were numerous examples in the literature of bespoke solutions falling short. While off-the-shelf solutions are not available for every possible use case, the level of effort required to adapt existing technology will always be lower than that of creating new technology from scratch.

Recommendation 4: NASA should provide training to both SMEs and educators

In order for digital expansion to be successful, the literature is very clear that training needs to be provided on two fronts. First, SMEs must be trained on how to adequately convey information (both generally and via the applicable technology). Second, educators must be trained on how to utilize the resources that NASA provides in such a way as to benefit students. This might also include on-site or help-desk support.

GAMING

Recommendation 5: NASA should utilize games to reduce student anxiety

One of the main reasons people play games is as a form of escape. In particular, games provide an opportunity to simulate real life without the inherent risks of real life failure. Many students are afraid to engage with active learning, because they are so concerned with loss of face due to failure. However, games provide an opportunity to try without any such fear, as a saved game can be reloaded or a board can be reset on a moment's notice.

Recommendation 6: NASA should utilize games to increase student choice

Another main reason that people play games is for the sense of control that they bring. Whether raising a family in *The Sims* or defeating a dragon in *World of Warcraft*, the player gets to choose their own methods and, sometimes, conditions for victory. All too often, the classroom involves the student being told what to do, when, and in what order. Games provide an opportunity for students to make their own decisions in a controlled environment.

Recommendation 7: NASA should utilize games to simulate real world STEM applications

In many cases, memorizing facts or computing solutions to equations provides no actual understanding of STEM concepts. To align with the conceptual understanding mandated by national standards, games can provide an opportunity for students to literally see how STEM concepts (i.e. gravity, air resistance, symmetry, etc.) effect real world scenarios (i.e. launching a rocket) because the game (i.e. Kerbal Space Program) does all the calculations in real time.

Recommendation 7a: NASA should develop an ARG where students roleplay as NASA employees

One of the biggest misunderstandings have about STEM is simply not having any idea of what scientists and engineers do for a living. Consequently, it is very difficult for students to imagine themselves growing up to enter a STEM career. NASA could provide an opportunity for students to roleplay as scientists and engineers, contributing to a simulated NASA mission that only reaches completion as students participate in the alternate reality game (ARG). Augmented reality, such as smartphone apps, could be combined with social media campaign that tracks the simulated mission.

Recommendation 8: NASA should "gamify" education only when doing so is appropriate to goals

Many people explore the role of games in education because they seek to infuse the fun of games into what is otherwise considered to be boring. However, the literature makes clear that learning gains are not made by educational games in those cases; the game, rather than the content, becomes the primary focus for students. Instead, NASA needs to identify learning goals first, then determine whether or not games or gamification is appropriate. For example

- Leader boards promote competition
- Achievement badges promote skill mastery
- Progress bars promote task completion

SOCIAL MEDIA

Recommendation 9: NASA should utilize social media to address large-scale issues

Large-scale issues, such as climate change, will not be resolved simply by conveying factual information. Only through sustained dialog will the national narrative conform to scientific consensus. Scientists have long recognized the need for such dialog between professionals, which is why academic journals exist. However, social media provides NASA an outlet through which STEM professionals can engage the public in similar conversation.

Recommendation 10: NASA should utilize social media to increase recruitment and retention

One of the main features of social media is passing along important information to friends (e.g. retweeting). Such word of mouth can both attract new participants to existing educational opportunities as well as reminding existing participants of new opportunities.

Recommendation 11: Any NASA social media should be authentic

Given the extent to which social media has been commandeered as an advertising platform, many people are leery of social media which is too polished or highly scripted. In other words, social media must seem to come from a person rather than an organization in order to be effective. The

literature identifies sharing of personal experiences, stories, opinions, and beliefs as social media content most likely to be perceived as authentic.

Recommendation 12: Any NASA social media should have positive emotional tone

The most successful social media to have "gone viral" almost universally utilize positive emotional tone, such as happiness, humor, and pleasant surprises.

SYNCHRONOUS VIDEO (I.E. VIDEOCONFERENCING / WEBCONFERENCING)

Recommendation 13: NASA should utilize synchronous video to represent and attract diversity

Generally speaking, the average person thinks that the average scientist is an elderly white male with crazy hair[138]. Live video provides an opportunity to provide concrete evidence that NASA (and STEM careers generally) are pursued by women, ethnic minorities, and other under-represented groups. Even ignoring demographics, such direct contact helps demonstrate that scientists and engineers are more than the two-dimensional geek or mad scientist stereotypes generally portrayed in television and movies.

ASYNCHRONOUS VIDEO (I.E. VIDEO SHARING SITES / TRADITIONAL TELEVISION)

Recommendation 14: NASA should utilize asynchronous video to promote content understanding

A YouTube video can, essentially, be watched anytime or anywhere. Additionally, a user can pause, rewind, and skip ahead in a video to emphasize the learning of most needed elements. In short, asynchronous video is the ultimate opportunity to learn-at-your-own-pace. While asynchronous videos cannot replace teachers, well-produced videos a powerful supplement that makes good teaching even better. If students watch asynchronous videos on their own time, the limited time that they have with an educator can be far more efficiently utilized.

Recommendation 15: NASA should keep asynchronous videos short

While it can occasionally be useful to archive an entire event or seminar, videos that are only a few minutes in length are generally more successful. Given an equal amount of content, the literature indicates that several short videos are more effective than one long video.

VIRTUAL LEARNING ENVIRONMENTS (I.E. ONLINE COURSES / MOOCS)

Recommendation 16: NASA should utilize a VLE in order to consolidate content

The simple fact of the matter is that the Internet is largely a realm of instant gratification. If users are required to have several logins to several websites in order to access all of NASA's educational materials, much of it will go unused. A VLE provides a mechanism by which to consolidate

multiple content elements into a single location. That is to say, a VLE provides a single place where, for example, three videos, a quiz, and simulation are all available on gravity.

Mobile Apps

Recommendation 17: NASA should utilize mobile technology to match changing Internet-use

While, even a few years ago, smartphones were a rare commodity, today smartphones and tablets are almost everywhere – particularly among youths. Simply in order to remain accessible to this fast-growing user base, NASA must make its digital assets mobile accessible.

Recommendation 18: NASA should utilize mobile technology to capitalize new opportunities

An Internet-connected smartphone is an accelerometer, a camera, a calculator, an encyclopedia, a microphone, and often so much more all at the same time. At no time in history has the average person been so capable of collecting, analyzing, and consuming information. Whether it be seeing the world in the infrared spectrum through the FLIR One camera or tracking stars in the most light-polluted city through the Google Sky Map app, NASA should capitalize on all the new opportunities mobile devices provide for STEM education that were simply unattainable in the past.

APPENDIX A: CROSSWALK OF GAMING TO COMMON CORE

Source: Kooiman, B. J., Kim, H., Wenling, L., & Wesolek, M. (2013). Linking the Educational Principles of Multiplayer Gaming and Play to Common Core Strategies. *International Journal of Technology in Teaching & Learning*, *9*(2), 189-204.

CCSS Construct	Serious Games Educative Principle	Relevant Research
Construct One: Focus on a deeper thorough understanding of pertinent content; help learners develop deep understanding of concepts in new situations.	**Identity:** Learner association with the learning outcome.	Kay, 2001; Roberts, 2011
	Interaction: Learner immersed in content and derives meaning from relevant interaction.	Csikszentmihalyi, 1996; Tracy & Colby, 2007
Construct Two: Precise complex and challenging content aligned with college and workforce needs; help teachers determine how to select learning materials.	**Explore, Think Laterally, Rethink Goals:** Learner explores content laterally to extend understanding.	Hess & Gunter, 2013; Wikersham & McGee, 2008
	Situated Meanings: Learner develops understanding through the setting and situation connected to the content.	Goel, Johnson, Junglas & Ives, 2010; Kemp, 2010
Construct Three: A coherent orderly sequence that provides uniform understandable clarity; provide a clear concise template aiding instruction, comprehension and assessment.	**Customization:** Learner self-selects from paths provided to aid in their understanding of content.	MacDonald, 2012; Stairs & Burgos, 2010
	Well-Ordered Problems: Learner benefits from pre-planned ordered instruction, lessons and curricula	Abell, Jung, & Taylor, 2011; Leinster, 2003
	"Just-in-Time" and "On Demand": Learner benefits from information when it is needed or useful.	Bellotti, Berta & De Gloria, 2010; Kirschner, Merriënboer & Kester, 2006

CCSS Construct	Serious Games Educative Principle	Relevant Research
Construct Four: Development of confident and capable learners; reduce redundancy to expedite learning	**Risk Taking:** Learner needs freedom to fail and learn from their choices and explorations.	Newton & Winches, 2014; Riggins, 2006
	Challenges and Consolidation: Learner is motivated by successfully applying what they know to new challenges	Geddes, 2010; Subramaniam, 2011
	Pleasantly Frustrating: Learners need to be challenged but not overwhelmed	Moore, 2002; Willingham, 2014
Construct Five: Research based curricula aligned to global standards; make clear the progression of content and learning through the use of big ideas.	**System Thinking:** Learner has a view of the big picture and understands how individual pieces fit together.	Boyle & Bragg, 2008; Tepfer & Lieberman, 2012
	Performance before Competence: Learner needs time to develop the competencies and skills required to perform task.	Jong et al., 2008; Robotham, 2004
Construct Six a: Provide a means for discerning student progress through verifiable methods: Increased informational writing in all subjects	**Production:** Learners who produce by writing have a positive effect on their own reading and learning.	Casteel, Isom, & Jordan, 2000; Graham & Hebert, 2011

CCSS Construct	Serious Games Educative Principle	Relevant Research
Constructr Six b: Provide a means for discerning student progress through verifiable methods:	**Agency:** Leaner takes ownership of their progress and develops a more sophisticated set of abilities and deeper understanding of the content.	Abigail & Laurie, 2005; Krotoski, 2010
Increased use of authentic performance tasks and project-based learning	**Smart Tools and Distributed Knowledge:** Learner shares knowledge and uses technology and tools to enhance their abilities.	Jong et al., 2008; Wendel, Gutjahr, Göbel, & Steinmetz, 2013
	Cross-Functional Teams: Learner benefits from cooperative teamwork wherein all members use their skills to accomplish a common goal.	Ghobadi & D'Ambra, 2012; Johnson & Delawsky, 2013; Wendel, Gutjahr, Göbel, & Steinmetz, 2013

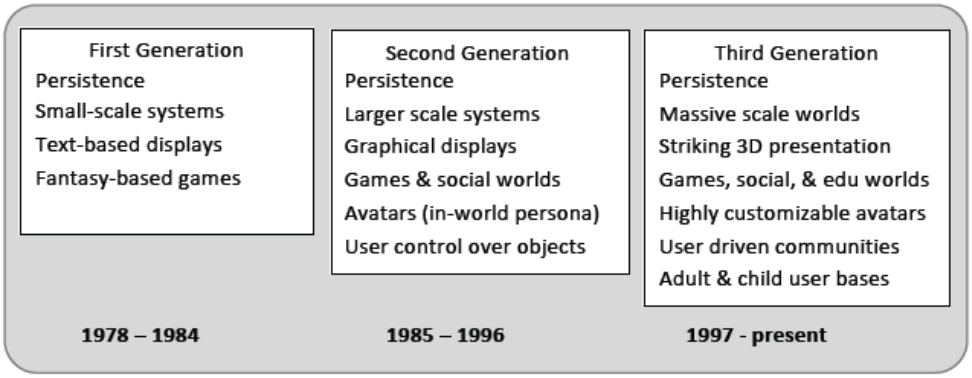
APPENDIX B: CROSSWALK OF RESEARCH ON TYPES OF GAMIFICATION

Source: Dicheva, D., Dichev, C., Agre, G., & Angelova, G. (2015). Gamification in Education: A Systematic Mapping Study. *Journal of Educational Technology & Society*, *18*(3), 75-88.

Design principles	Used game mechanics	Papers
Goals: specific, clear, moderately difficult, immediate goals		Lee & Hammer, 2011 Kapp, 2012b
Challenges and quests: clear, concrete, actionable learning tasks with increased complexity		Lee & Hammer, 2011 Zichermann & Cunningham, 2011 Deterding, 2013 Simões, Díaz, & Fernández, 2013
Customization: personalized experiences, adaptive difficulty; challenges that are perfectly tailored to the player's skill level, increasing the difficulty as the player's skill expands		Lee & Hammer, 2011 Zichermann & Cunningham, 2011 Simões, Díaz, & Fernández, 2013 Gordon, Brayshaw, & Grey, 2013
Progress: visible progression to mastery	Points, progress bars, levels, virtual goods/currency	Zichermann & Cunningham, 2011
Feedback: immediate feedback or shorten feedback cycles; immediate rewards instead of vague long-term benefits		Lee & Hammer, 2011 Nah et al., 2014 Zichermann & Cunningham, 2011 Kapp, 2012b Simões, Díaz, & Fernández, 2013 Gordon, Brayshaw, & Grey, 2013
Competition and cooperation/social engagement loops	Badges, leaderboards, levels, avatars	Zichermann & Cunningham, 2011 Iosup & Epema, 2014 Deterding, 2013 Simões, Díaz, & Fernández, 2013
Accrual grading	Points	Simões, Díaz, & Fernández, 2013
Visible status: reputation, social credibility and recognition	Points, badges, leaderboards, avatars	Lee & Hammer, 2011 Deterding, 2013 Simões, Díaz, & Fernández, 2013
Access/unlocking content		Iosup & Epema, 2014
Freedom of choice: multiple routes to success, allowing students to choose their own sub-goals within the larger task		Lee & Hammer, 2011 Iosup & Epema, 2014 Deterding, 2013 Simões, Díaz, & Fernández, 2013
Freedom to fail: low risk from submission, multiple attempts		Lee & Hammer, 2011 Kapp, 2012b Deterding, 2013 Gordon, Brayshaw, & Grey, 2013
Storytelling	Avatars	Nah et al., 2014 Kapp, 2012b Simões, Díaz, & Fernández, 2013
New identities and/or roles	Avatars	Lee & Hammer, 2011 Simões, Díaz, & Fernández, 2013
Onboarding		Zichermann & Cunningham, 2011
Time restriction	Countdown clock	Kapp, 2012b

APPENDIX C: HISTORY OF VIRTUAL WORLDS

Source: Downey, S. (2014). History of the (Virtual) Worlds. *Journal Of Technology Studies*, *40*(2), 54-66.



First Generation Worlds (1978-1984)

Avatar	Introduced the practice of "spawning" (e.g., re-populating a world with monsters/characters) and facilitated players' communications to be more collaborative.
Maze Wars	Multiplayer environment incorporating wireframe graphics, giving the illusion of a 3D maze in which players interacted.
MUD (aka MUD1)	Multi-User Dungeon, arguably the first virtual world; initiated by Roy Trubshaw and finished by Richard Bartle in 1979.

Second Generation Worlds (1985-1996)

Habitat	Technology Experience
Meridian59	First commercial game to directly employing the Internet versus proprietary networks like CompuServe or AOL.
MOO	MUD Object Oriented provided a robust scripting language that allowed users to create in-world objects for social-oriented worlds.
TinyMUCK	First world to allow users to create objects from within the virtual world.
TinyMUD	One of the first worlds to focus on social interactions versus gaming and combat; in doing so, it promoted a new genre of virtual worlds.

Third Generation Worlds (1997-present)

EverQuest	Designed to encourage group play, EverQuest stood at the de facto standard in virtual worlds prior to the arrival of World of Warcraft.
Habbo	The most popular virtual world, in terms of user accounts created, although it hasn't become the cash cow that World of Warcraft was.
Second Life	Highly popular world, especially in the education arena, due to its extremely diverse content and ability for users to create and collaborate together on projects, activities, and lessons.
Ultima Online	Ushered in the third generation of worlds by introducing a wide array of changes in virtual world design, including variable playing styles (e.g., casual vs. hard-core gamer) and new graphical views versus the traditional overhead view.
World of Warcraft	Due to its eye-catching graphics and numerous gaming innovations, World of Warcraft captured 50% market share among subscription-based MMOGs for more than four years, making it the most commercially successful virtual world to date.

APPENDIX D: SECONDLIFE VERSUS OPENSIM

Source: Coban, M., Karakus, T., Karaman, A., Gunay, F., & Goktas, Y. (2015). Technical Problems Experienced in the Transformation of Virtual Worlds into an Education Environment and Coping Strategies. *Journal Of Educational Technology & Society*, *18*(1), 37-49.

3D Platform	Potential problems that may be encountered in the environments
OpenSim	• There are server problems. • The computers have inefficient technical features, and this results in the problem of freezing. • It is not possible to retrieve the objects deleted in the environment. • It is not easy to activate the oral communication options. • It is not possible to download the objects from the server, or it takes time to do so. • It is not easy to activate the multimedia add-ons. • The interface software used to access the environment does not allow easy designing of objects. • There are not enough sources appropriate to the native language regarding the software. • The design process takes a lot of time and requires effort. • The coordinates of the objects are confusing and make the design process difficult. • It is not possible to find enough technical information or to receive help. • The audio files in the 3D environment support the users for only 10 seconds at most. • It is very difficult to develop interactions between 3D objects or the physcial simulations. • Users making designs and developments in the 3D environments complain about the complexity of the interfaces used to access the environment, and there are motivational problems due to the users' expectations and desire make the design process easier.
Second Life	• The procedures for purchasing an island in the SL environment are long, complex, and time-consuming. • The computer equipment must possess the required technical features so that the environment can work. • There are not enough sources in Turkish related to the platform. • The development process for the multimedia objects takes a long time, and it is difficult to control the objects. • The avatar options provided by the environment are not appropriate to the educational content. • The audio files in the 3D environment support the users for only 10 seconds at most. • It is not easy to develop interactions between the 3D objects or physical simulations. • There are problems with authority and permissions. • Users making designs and developments in the 3D environments complain about the complexity of the interfaces used to access the environment, and there are motivational problems due to the users' expectations and desire make the design process easier. • It is not possible to retrieve the objects deleted in the environment. • More than one person can use the same media elements simultaneously. • Dialogue boxes constantly open to ask for approval to activate the animations. • Users have difficulty putting on, purchasing, and changing the clothes for their avatars when using the interactive objects found in the environment, or they fail to do so appropriately. • The web add-ons designed for the users fail to work well, and they allow more than one person to use the same media elements simultaneously. • It is difficult to control the interface with the input devices.

APPENDIX E: COMPARISONS OF SYNCHRONOUS VIDEO PLATFORMS

Below is the standard comparison that Paragon TEC provides regarding synchronous video.

Connection Type	Platform	Pro	Con
Videoconference	Tandberg, Cisco, Polycom, Life Size	Good Video and Audio. Ability to display video and graphics	Bandwidth, Costly
Vidyo	Laptop or Desktop with Windows, Mac OS, Mobile platform	Good Video and Audio, has chat and sharing capability, Cost Free	Firewall issues
Conference Me	Laptop or Desktop with Windows only OS	Good Video and Audio. Cost Free	Not available for MAC OS
Polycom Realpresence	Laptop or Desktop with Windows, Mac OS, Mobile platform	Video and Audio ok. Cost Free	No Chat or screen sharing
Adobe Connect	Laptop or Desktop with Windows, Mac OS, Mobile platform	Video is ok, has chat and sharing capability.	Has Audio issues at times
Blackboard Collaborate	Laptop or Desktop with Windows, Mac OS, Mobile platform	Wide variety of interactivity and logging features	Requires installation of Java which is considered to be insecure
Google Hangouts	Laptop or Desktop with Windows, Mac OS, Mobile platform	Video is ok, has chat and sharing capability.	Limited number of connections and quality/speed is variable.

Below is another comparison from peer-reviewed literature[139].

	Advantages	Disadvantages
DimDim	Low cost	Lack of multi-camera support
	Ease of use	Lack of screen-size scalability
	Many basic features	Limited applications-sharing
	Help tools	
Elluminate VCS	High-quality audio and video	Cost
	Easy applications-sharing	Lack of Help tools
	Interoperability with dedicated videoconferencing equipment	
	Good scheduling tool and presence engine	
TokBox	Low cost	No whiteboard
	Good-quality video	Most tools not integrated into the software
	Can send video emails	
	Simple meeting requests/set-up	
	Can use various web applications	
Vyew	Low cost	Lack of screen-size adjustment
	Synchronous or asynchronous collaboration	Banner advertising
	Voice recordings and sticky notes can be pasted into shared workspace	
	Web-based plug-ins can easily be introduced into the workspace	

APPENDIX F: FACTORS INFLUENCING VIDEOCONFERENCE SUCCESS

CONSTRUCT	INDICATOR	DESCRIPTION
EASY	Easy1	Students' think it was easy to follow the lesson through VC
	Easy2	Appropriateness and simplicity of teacher-student interaction
	Easy3	The degree to which students were able to easily understand the content
	Easy4	The degree to which the technological solution fitted learning requirements
ATTITUDE	Att1	Acceptance of VC during the lessons
	Att2	Beliefs regarding possibility to bridge the distance between the teacher and the students
	Att3	Attitude towards new interactive technological solutions for learning
MOTIVATION	Motiv1	Level of motivation to attend VC based classes in the future
	Motiv2	Beliefs to recommend and motivate others to attend similar classes
	Motiv3	Level of motivation for attendance to satisfy job requirements
	Motiv4	Level of motivation to use the recorded VC session for learning
TECHNICAL	Tech1	Students' perceived quality of the video signal
	Tech2	Students' perceived quality of the audio signal
	Tech3	Beliefs regarding proper audio/video synchronization
	Tech4	Students' perceived level of proper functioning of the equipment
QoE	QoE1	Perceived experience for the comfort during learning and increased efficiency
	QoE2	Perceived experience for increased possibilities for learning and productivity
	QoE3	The degree to which students think this type of learning is interesting and enjoyable
	QoE4	Overall experience during distance learning enhanced with VC

Source: Malinovski, T., Vasileva-Stojanovska, T., Jovevski, D., Vasileva, M., & Trajkovik, V. (2015). Adult Students' Perceptions in Distance Education Learning Environments Based on a Videoconferencing Platform -- QoE Analysis. Journal Of Information Technology Education, 142-19.

Factors/Constructs	*Items*	*IS source*	*Source from e-Learning research*
Computer Self-Efficacy (CSEF)	I could complete my learning activities using a webcast if there was no one around to tell me what to do. (CSEF1) I could complete my learning activities using a webcast if I had only instructions for reference. (CSEF2) I could complete my learning activities using a webcast if I had never used it before. (CSEF3) I could complete my learning activities using a webcast if I had seen someone else using it before trying it myself (CSEF4)*	Compeau and Higgins 1995	Shih 2008
Effort Expectancy (EE)	Educational webcasts are easy to use. (EE1) The process of using educational webcasts is clear and understandable. (EE2) It is easy for me to become skilful in using educational webcasts. (EE3)	Venkatesh *et al* 2003	Hsu and Lin 2008; Ngai *et al* 2007
Performance Expectancy (PE)	Educational webcasts are very useful to me. (PE1) Using educational webcasts improves my performance. (PE2) Using educational webcasts enhances the effectiveness of my learning. (PE3) Using educational webcasts would make it easier to learn. (PE4) Using educational webcasts increases my learning productivity. (PE5)	Venkatesh *et al* 2003	Sanchez-Franco 2010
Perceived Behavioral Control (PBC)	I would be able to use educational webcasts. (PBC1) I have the knowledge and the ability to use educational webcasts. (PBC2)	Taylor and Todd 1995	Shih 2008
Social Norm (SN)	People who are important to me think that webcasts should be used for learning. (SN1) People who influence my behavior encourage me to use webcasts for learning. (SN2)	Venkatesh *et al* 2003	Hsu and Lin 2008
Behavioral Intention (BI)	I plan to use webcasts for learning in the future. (BI1) I intent to continue using webcasts for learning in the future. (BI2) I thing webcasts should be implemented in learning. (BI3) I expect my use of webcasts to continue in the future. (BI4)	Bhattacherjee 2001	Lee, Yoon & Lee, 2009
Experience of Using Webcast (EXP)	How many times (approximately) have you used learning webcast in the past six months? (EXP)	Chiu, Lin, Sun and Hsu 2009	

*Deleted due to a low factor loading.
IS, Information Systems.

Source: Giannakos, M. N., & Vlamos, P. (2013). Educational webcasts' acceptance: Empirical examination and the role of experience. British Journal Of Educational Technology, 44(1), 125-143. doi:10.1111/j.1467-8535.2011.01279.x

APPENDIX G: EXAMPLE SURVEY PROTOCOLS

Source: Falloon, G. (2012). Using videoconferencing in a school-scientist partnership: students' perceptions and scientists' challenges. *Research In Learning Technology*, *20*(3), 1-18. doi:10.3402/rlt.v20i0.17194

Scientist focus group (semi-structured)

Interview starter questions

Additional questions to be generated according to responses

(Introduce, thank, brief on recording procedure, data use, confidentiality, anonymity etc.)

(1) How did you come to be involved in the videoconference workshops and labs?
(2) Why did you agree to participate? (have you done anything like this before?)
(3) Can you talk a bit about the preparation you needed to do to before the workshops and labs?
(4) Overall, what is your opinion of how well they went? (how do you know?)
(5) As presenters, were there any issues for you when delivering your workshops and/or labs? (explain and describe)
(6) Do you consider videoconferencing to be an effective medium for delivering content and practical demonstrations to students? (explain and describe)
(7) What did you as scientists get out of the experience? (explain and describe)
(8) What do you think the students got out of the experience? (explain and describe)
(9) Thinking more broadly would you consider participating in these on a wider scale a viable option for you? (more schools, broader science).

Participant teacher interview questions (semi-structured)

Starter questions

Additional questions will be asked according to responses

(Introduce, thank, brief on recording procedure, data use, confidentiality, anonymity etc.)

(1) How did you and your class come to be involved in this programme (Science-for-Life)?
(2) Can you tell me your reasons for linking with (institute) for this series of videoconferences? (explain and describe aims and goals)
Were your goals and objectives met? (how? how do you know?)
(3) Can you describe the preparation that went on at your end for the videoconference workshops and labs?
(4) What do you think your students got out of the videoconferences (workshops and labs)? Were you happy with your students' performance? (explain and describe).
(5) Did you follow up on the content of the videoconferences in class? (how, and in what way?)
(6) Were there aspects of the videoconferences you felt might have been improved? (explain and describe)
(7) What do you consider to be benefits of using videoconferencing in this way? (explain and describe). Any limitations? (explain and describe).
(8) The workshops and labs had quite different purposes and approaches. Can you comment on the value and success of each, and any issues you consider affected this?

Student Questionnaire

Science-for-Life Videoconference Workshops and Labs

Please indicate your response to the following statements relating to your experiences in the (institute) videoconference workshops and labs.

For all statements, a ranking of 5 means complete agreement, while a ranking of 1 means no agreement.

(1) I consider the videoconference **teaching workshops** to be worthwhile learning experiences

no agreement — complete agreement

1 2 3 4 5

(2) I consider the videoconference **'virtual labs'** to be worthwhile learning experiences

no agreement — complete agreement

1 2 3 4 5

(3) I developed new science knowledge useful to my studies, through the videoconferences (teaching and labs)

no agreement — complete agreement

1 2 3 4 5

Please detail briefly what this was:

(4) I developed new science knowledge of interest, but not directly related to my studies, through the videoconferences (teaching and labs)

no agreement — complete agreement

1 2 3 4 5

Please detail briefly what this was:

(5) The videoconferences added authenticity to the science I am learning at school (teaching and labs)

no agreement — complete agreement

1 2 3 4 5

(6) I developed new knowledge related to the work of scientists, through the videoconferences (teaching and labs)

no agreement — complete agreement

1 2 3 4 5

(7) I consider the videoconference helped further my interest in, or enthusiasm towards, science

no agreement — complete agreement

1 2 3 4 5

(8) I found the format of the videoconferences appropriate

no agreement — complete agreement

1 2 3 4 5

(9) I found the content and language of the videoconferences was pitched appropriately

no agreement — complete agreement

1 2 3 4 5

(10) I consider 'virtual labs' superior to the teaching workshops for my learning

no agreement — complete agreement

1 2 3 4 5

(11) I could see and hear the videoconferences clearly

no agreement — complete agreement

1 2 3 4 5

(12) I felt confident to contribute to the videoconferences (e.g., through asking questions, offering opinions)

no agreement — complete agreement

1 2 3 4 5

(13) I consider videoconferences to be an effective medium for my learning

no agreement — complete agreement

1 2 3 4 5

(14) I would like more videoconferences in my courses

no agreement — complete agreement

1 2 3 4 5

Student interview schedule (semi-structured) following questionnaire

Starter questions

Additional questions will be asked according to responses

(Introduce, thank, brief on recording procedure, data use, confidentiality, anonymity etc.)

(1) Firstly, do you think the videoconferences were worthwhile? (Separate – workshops, virtual labs). Why or why not? (Elaborate and expand)

(2) What sort of things did you learn from them that you found useful? (if necessary, introduce by discussing differences in questionnaire results between study-related and other knowledge, ideas around authenticity, understanding of science and work of scientists etc.) Elaborate and expand as appropriate.

(3) Results from the questionnaire generally suggest students found the teaching workshops more valuable than the virtual labs. Can you tell me something about that?

(4) Results from the questionnaire suggest students didn't feel that confident to ask questions or interact with scientists during the workshops and labs. Can you tell me why that might have been? (Elaborate and expand) (Talk briefly about teacher comment that most useful discussion happened following each conference)

(5) From your point of view, how might the videoconferences have been improved? (prompts: interaction, technical, content, pace, volume/clarity, room layout etc.)

(6) Overall, do you think videoconferencing is an effective way for you to learn? (how, why/not etc.)

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