Best Practices for Creating and Leading Active-Learning Workshops in Academic Makerspaces

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Abstract

Workshops are effective tools for introducing makerspace technologies. Active-learning workshops where face-to-face time is spent working on projects are well received by students, especially non-engineering students. Flipped-learning pedagogies facilitate primarily hands-on workshops by moving instruction into pre-workshop activities. Effective flipped workshops start with learning outcomes which are SMART: Specific, Measurable, Attainable, Relevant, and Time-based. In-class activities should be active, and contextual – just-in-time learning, not just-in-case learning. Student choice and relevance motivate students in their learning. Differentiation through pre-workshop instruction and modularized face-to-face activities allows learners to work at their own pace and choose what interests them, rather than a forced march tutorial/lecture. Lastly, instructors should lead workshops as "guides on the side" rather than "sages on the stage." This paper, and associated linked documents, serves a guide for creating and running active-learning workshops in academic makerspaces.

Introduction

Flipped, active-learning workshops not only make efficient use of limited makerspace time and space, but also allow participants to work through instructional materials at their own pace and devote the majority of face-to-face time to hands-on activities [1]. This is done by moving the majority of instruction into online modules to be completed before the workshop starts. Flipped, active-learning instruction contrasts with common makerspace pedagogies of peer-to-peer instruction, or in some cases lecture based instruction followed by hands-on activities [2]. While individual peer-to-peer instruction is the preferred way to meet the needs of makerspace users in many cases, students without previous makerspace experience will often choose the workshop format over peer-to-peer, as workshops do not require that the student have a project in mind and can be an introduction without the perception of any obligation beyond the workshop [3].

When creating or updating a new workshop, typically the first step is to identify the learning outcomes, which are the things that you want workshop participants to be able to do or know by the end of the session. Ideally, these learning outcomes or goals will be created in the SMART format: Specific, Measurable, Attainable, Relevant, and Time-based [4].

While the majority of flipped workshop face-to-face time should be "hands-on", those activities should be of an active nature as there is significant evidence that active-learning, even when reducing classroom time, leads to higher achievement on "standardized exams, and students' perceptions of their learning environment are improved" [5]. In addition there is considerable evidence that active-learning activities, "significantly improve recall of information while extensive evidence supports the benefits of student engagement" [6].

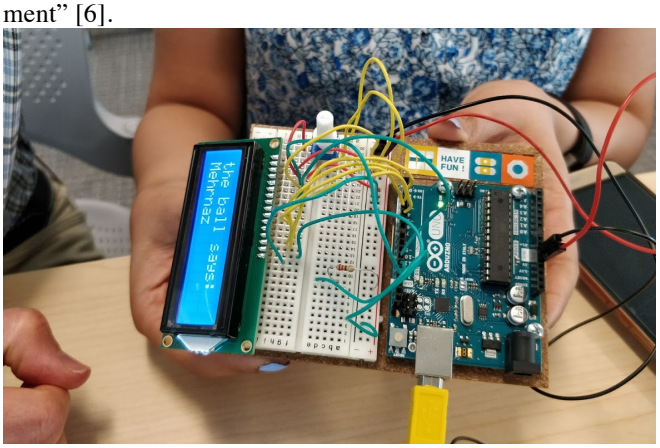

Fig.1 Hands-on electronics activity.

Engagement, by including opportunities for learner choice, has also been shown to increase the "retention of information. When students are permitted to choose activities which 'turn them on,' they become more aroused in the learning situation and, if the arousal data is predictive, retain what they learn." [7].

The flipped and active teaching method can also facilitate differentiated learning for workshop participants, in the form of self-pacing and learner choice. The majority of makerspace workshop participants surveyed over three years either agreed or strongly agreed that it was helpful to work through the pre-workshop instruction at their own pace. The desirability of working at their own pace was also mentioned by some survey participants as an advantage of the flipped, active workshop format [3]. Corry and Carlson-Bancroft report that, "flipping the classroom establishes a framework that enables teachers to effectively differentiate and personalize instruction so it is tailored to meet each student's individual needs. During one-on-one interactions the teachers are able to work with the individual students to quickly correct misconceptions that keep them from mastering the content allowing the direct instruction to be asynchronous, so differentiation for each student becomes possible" [8].

Contextual, or just-in-time learning can also lead to higher participant engagement during workshops by "anchoring learning in meaningful contexts" [9]. It is intuitive that if workshop participants are learning a new skill that will help

them solve an immediate problem they have, or to complete a project they are working on, they will be more motivated to learn the skill being taught. Not surprisingly, "just-in-time teaching appears to increase students' motivation or disposition to spend more time and effort on course objectives and their engagement, or the actual time and effort spent on course work" [9].

Theoretical frameworks

A. *Cognitive Load Theory (CLT)*

Learning theories can be useful tools to exploring teaching methods, like flipped, active-learning. Cognitive Load Theory (CLT) explains why human short-term memory, after trying to remember sometimes no more than two or three items, becomes overwhelmed and learning suffers [10]. Flipped learning pre-training, in the form of pre-class videos, is one way in-class cognitive load can be reduced to manageable levels by moving instruction out of face-to-face workshop time and allowing students to watch videos at their own pace and multiple times if necessary. Pre-training also helps differentiate instruction for students with different levels of knowledge and ability, and allows students with less knowledge to prepare for the workshop and arrive closer to the same level as their classmates. Workshop participants can spend as much or as little time as necessary to fully prepare for a workshop so that there is no need for the whole class to endure a "forced march" lecture through the instruction at the pace of the slowest learner in the group [11].

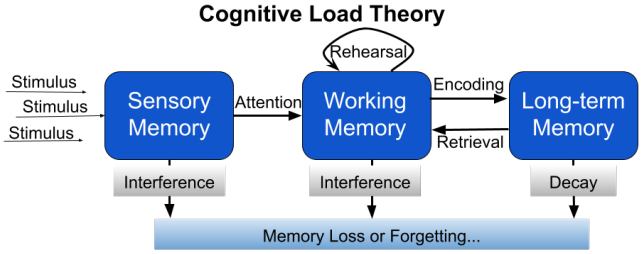

Fig.2 Cognitive Load Theory.

CLT helps describe why a flipped, active-learning makerspace workshop pedagogy can be effective. Short-term working memory is like a computer buffer. If it is not able to process the information inputs into long term storage before it is full, then it overflows and information is lost.

A. *Constructivism*

Constructivist learning theory describes how we learn. New knowledge is built on the learner's experiences and background and is often project or problem-based. For example, the instructor's primary role when using a constructivist teaching method is to guide the learner and help them problem solve when needed, encouraging them to question, challenge, and arrive at their own conclusions [12]. Some of the earliest proponents of constructivist pedagogies include Maria Montessori, John Dewey, and David Kolb [13].

Active, meaningful, project or problem-based learning activities are often used in conjunction with flipped learning curriculums. If carefully prepared and paired with appropriate pre-workshop "scaffolding" work, these activities can help learners acquire skills more quickly than in lecture based instruction [14].

Workshop design process

As with most projects, it is best to begin with the end in mind. When creating an active-learning workshop for an academic makerspace, this means starting by identifying the learning outcomes that you want participants to leave your workshop knowing how to do. Next, in-workshop activities need to be created to cover all or as many of the skills-based learning outcomes as possible, followed by pre-workshop instruction to convey as much fact based learning outcomes as possible. Following this, a short introductory presentation can be developed to orient participants at the beginning of the workshop. Lastly, a post-workshop evaluation should be designed in order to give continual feedback to the owners, maintainers, and instructors of the workshop directly from workshop participants. It should be noted that the order that the elements of a workshop are created are not the same order that they are delivered in. This is by design, as for example, it is helpful to create pre-workshop materials after the workshop activities are created so that any learning outcomes not covered, or covered well, in the activities can be given the appropriate attention in the pre-workshop materials.

The first step however, is to identify and vet the new workshop topic to make sure it is appropriate for a makerspace.

A. *Workshop Topics*

A new workshop usually begins to take shape with the selection of an appropriate topic for an introductory workshop. The topic should be something that a makerspace has expertise in, and the tools and space to effectively teach. If either of those elements is missing, a plan should be made for one or more members of the makerspace staff to acquire the expertise, and/or acquire the tools necessary to offer the workshop.

Makerspaces often already have the tools and expertise, and are looking ways to make a workshop more accessible to non-engineering students, or scale up instruction for a particular tool from the typical one-on-one instruction common in makerspaces to something that makes more effective use of staff or volunteer time. Some example introductory workshop topics are: "Introduction to 3D Design and Printing," "Introduction to Version Control with GitHub," and "Introduction to Programmable Electronics with Arduino" [15].

B. *Learning Outcomes*

The next step in the workshop creation process is to create learning outcomes for your workshop, while making sure you keep your target audience, or prospective learners in mind.

- Who are your target audiences?
- What is their age and educational focus?
- Do they have experience with the topic you chose, or something closely related?

- What do you think your potential audience would like to get out of the workshop?

Don't be afraid to ask colleagues and prospective learners what they would like to get out of your proposed workshop. Occasionally you may find that the topic is not as popular as you thought it was, but it is far better to find that out at this point before investing a lot of time and effort into a workshop that has no significant demand.

If you are an expert in the workshop topic, it is often difficult to remember what things you do not need to explain in detail and which things require lengthier explanations. This phenomenon is sometimes called the curse of expertise, because the expert cannot remember what it is like to be a novice [16]. Because of this it is important to beta-test any new workshop with at least one or two trusted novices, so that accurate feedback can be acquired to determine which areas need more explanation, and which areas you have possibly elaborated on too much.

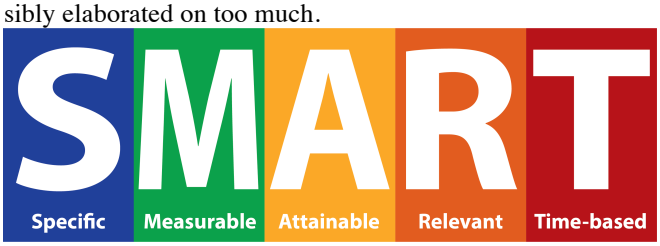

Fig.3 SMART learning outcomes [17].

"Begin with the end in mind" [18] - Learning outcomes should each be SMART: Specific, Measurable, Attainable, Relevant, and Time-based [19].

- Specific: Exactly what is to be learned - who, what, where, why?
- Measurable: How will it be determined that the specific learning outcome has been met?
- Attainable: Ideally challenging learning outcomes within the ability of participants to achieve. Not out of reach, but not too easy.
- Relevant: How do the learning outcomes relate to the needs and desires of the workshop participants?
- Time-based: When will the learning outcome be successfully completed? During or at the end of the workshop? At a future workshop or future date?

Look for each of the five SMART elements in the following three example makerspace learning outcomes:

- "By the end of this workshop, participants will be able to add new shapes and text to the TinkerCad workspace in order to create the compound object(s) they desire."
- "By the end of this workshop, participants will be able to verbally describe to the instructor the copyright and sharing issues around 3D design and printing."
- "By the end of this workshop, participants will have created an Excel scatter plot chart and trend line using their own data (or sample data), and shared it with the instructor."

Typically, poor learning outcomes describe workshop content, but not the attributes of successful completion, including the subject of learning being too vague for assessment [15].

By the end of the workshop the learner will be able to:

	Learning Outcome	Analysis
Option 1: Not an outcome	Be given opportunities to learn effective communication skills	Describes program content, not the attributes of successful students
Option 2: Vague outcome	Have a deeper appreciation for good communication practices	Does not start with an action verb or define the level of learning; subject of learning has no context and is not specific
Option 3: Less vague outcome	Understand principles of effective communication	Starts with an action verb, but does not define the level of learning; subject of learning is still too vague for assessment
Option 4: Specific outcome	Communicate effectively in a professional environment through technical reports and presentations.	Starts with an action verb that defines the level of learning; provides context to ensure the outcome is specific and measurable

Fig.4 Examples of Learning Outcomes: Good and Bad [15]

After creating appropriate learning outcomes for a workshop, a determination needs to be made to estimate if the learning outcomes can be achieved within the parameters of a typical makerspace workshop. Workshop parameters typically include:

- Estimate the length of time it will take to achieve each of the learning outcomes.
- How much time do you have to run the workshop? 60 minutes, 90 minutes, all day?
- If tools or equipment are essential to the workshop, how many participants can reasonably use the equipment/tools and still achieve the learning outcomes?
- How many instructors and/or teaching assistants are available to teach the workshop?
- How many people can the room lab or makerspace accommodate?

Keeping the parameters of the new workshop in mind, how do we narrow down our learning outcomes if it seems like we do not currently have access to the resources to complete? Some options for slimming down a workshop or expanding it are:

- Split up the workshop into more than one session.
- Determine what learning outcomes can be moved into an intermediate workshop.
- Drop one or more learning outcomes.

C. In-workshop Hands-on Activities

When thinking about and creating activities for a flipped, active-learning workshop, there are few guidelines to keep in mind that can help to ensure that your activity is as engaging and as relevant as possible:

- Active: Get participants actively engaged in skill development for as much time as possible. Less lecturing or sage on the stage, and more assisting or guide on the side.
- Contextual: Just-in-time learning to help participants with immediate problems or needs, not just-in-case learning.
- Choice: Students should be given as much choice in activity selection as is possible during the workshop.

- Differentiated: Allow participants to work at their own pace, and to customize the workshop with differentiated scaffolding to accommodate the various skill levels that they bring with them.
- Connect to Prior Knowledge: Connect new skills in the workshop to prior knowledge.

One should always refer back to learning outcomes when thinking of activities that will that can help meet one or more of the learning outcomes. Ideally contemplated activities will incorporate all of the active-learning guidelines: active, contextual, provide choice, be differentiated, and connect to prior knowledge. It's not always possible to create an activity that can follow all of those guidelines, but one should try to incorporate as many as possible.

Next, the activity should be fleshed out with high-level steps and sub-steps so that someone with little to no experience can complete the activity. Graphics (or videos when the instruction is online) should be inserted where a visualization could help participants better understand what they need to do better than with just text alone. Creative Commons licensed images can be copied and pasted into your workshop activity document and then appropriately cited. Here is an example of an activity handout for an introductory Arduino workshop: http://bit.ly/2yB7BN5 [20].

Multiple activities may need to be created to cover all of the learning outcomes for a workshop and can help differentiate a workshop for different skill levels and different participant learning goals. For example, the authors created five separate activities to cover all of the identified learning outcomes for an introduction to Excel workshop. The participants were encouraged to complete only the activities that were interesting or relevant to them. In addition, some participants had experience with Excel, so they could skip ahead to the more advanced activities. For some participants, creating a Pivot-Table was an important skill to acquire, while most simply wanted to learn how to use basic Excel functions, and create charts and tables from the results. Using multiple activities each with their own handout gives participants choice, and the ability to work at their own pace while having an instructor on hand and available to answer questions. Here is the instructor's outline document for a Microsoft Excel workshop: http://bit.ly/2wi60e1 [21].

D. Pre-workshop materials

It is typically helpful to create or find overview videos or documents to orient workshop participants to the technology or skill they will learn. Refer back to the SMART learning outcomes created, and identify all that you have not covered in the in-class activities so that those learning outcomes can be covered in pre-workshop videos or readings.

Instructional videos created by higher education institutions on are often made available for free on YouTube, which can be shared with your workshop participants to prepare them to successfully engage in face-to-face active-learning activities. Creating a custom video gives the workshop creator full control, but at the cost of significant time and effort. Here are two important things to keep in mind as pre-workshop materials are found or created:

1. The instructional differentiation that pre-workshop videos and readings provide is particularly helpful when workshop participants have differing levels of knowledge and experience about the workshop topic. Those with more background can skim the videos, while those with less background can watch the videos more than once. In the case of students with comprehension issues or accessibility needs, closed-captioning can be turned on, and the videos can be watched multiple times [11].
2. Where pre-workshop videos and documents are distributed are largely dependent on the institution a makerspace is situated in, however some common distribution platforms are: email, YouTube, learning management systems, web pages, Github, and Google Docs. These are all platforms that can be used to quickly and easily share pre-workshop instructional materials with participants.

In order to help learners know if they are fully prepared to participate in the face-to-face workshop, creating a pre-workshop quiz to give them direct and timely feedback can be helpful. A pre-workshop quiz typically does not need to be long if well crafted. For a 60 or 90 minute workshop, it is the experience of the authors that between four to eight questions are sufficient to let learners know if they need to review the pre-workshop materials further. In the examples below, attempts were made to have some fun with the quiz questions from an Introduction to Electronics with Arduino Pre-Workshop Quiz (the correct answers are italicized):

Q1: Have you installed the Arduino software on your laptop (if you have a laptop)?

a) Yes
b) No

Q2: A breadboard is:

a) Something that we cut bread on
b) A solderless device for prototyping with electronics
c) What you bake bread on

Q3: What do resistors do?

a) Resist the government
b) Regulate the flow of electricity
c) Regulate the flow of butter on to the breadboard

Here is a link to a sample pre-workshop quiz: http://bit.ly/2OEFyaJ [22].

Pre-workshop instruction

Once the pre-workshop instruction materials have been organized or created, and a distribution method organized, the instruction largely takes care of itself. In the case of the University of Victoria Libraries Digital Scholarship Commons (a library based makerspace), pre-workshop instructional materials are distributed to workshop participants via direct links to videos and documents in the Eventbrite confirmation email they receive after signing up for the workshop. A follow-up Eventbrite email is sent to them two days before the workshop to remind them of the workshop date and time, and the pre-workshop materials to be reviewed in case they have not covered them already. This follow up email is an important detail.

When a professor has requested a workshop for their for-credit class, an email is sent to the professor with a link to the instructional document for the workshop, which includes learning outcomes, links to pre-workshop materials, and links to the in-workshop activity handouts for them to review. Typically the professor will only forward on to their students the pre-workshop materials via an email or via the campus learning management system.

At the University of Victoria Libraries, currently approximately half of workshop participants complete some or all of the pre-workshop videos and/or readings. Typically the participants who need more support, or who are nervous about technology complete the pre-workshop exercises[11].

Face-to-face workshop instruction

The face-to-face portion of the workshop is where the flipped, active-learning teaching method has the greatest self-reported positive impact on participants with 66% of all participants reporting that they preferred or strongly preferred the hands-on, active-learning format of the flipped workshop compared to a more traditional lecture based instruction. When librarians and university staff are removed from the analysis, the percentage of responding participants who preferred or strongly preferred the flipped active-learning teaching method rises to 86%. In addition, 92% of responding participants appreciated the ability to work at their own pace, which the flipped teaching method affords, and 78% preferred the workshop format for an introduction to a new technology rather than peer-to-peer tutoring that is commonly used in makerspaces: http://bit.ly/2yBuDU7 [23].

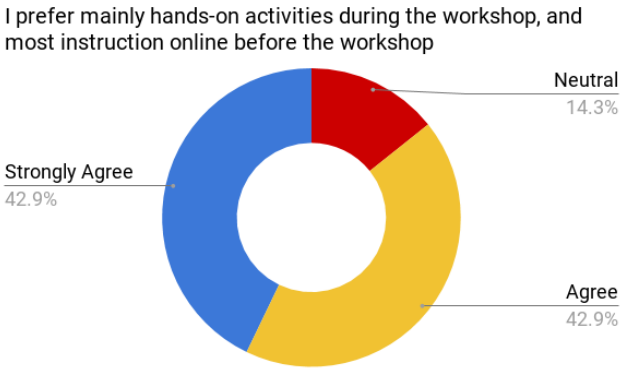

Fig.5 Preference for hands-on activities compared to lectures [23].

In order to devote most of the face-to-face workshop time to hands-on, active-learning activities, the introduction should ideally last no more than five to ten minutes. The introduction is also where the instructor sets the tone for the workshop, and teachers who are seen to be excited about what they are teaching see that enthusiasm reflected in the performance of workshop participants [24]. This introduction should be the only "sage on the stage" portion of the workshop. After the introduction is over, the instructor should shift into more of a "guide on the side" mode, and assist participants one-one one, or in small groups.

Also in the introduction, if the group is not too large (fewer than 10-15 participants) it can be helpful to ask each person to introduce themselves personally and tell the group one thing they hope to get out of the workshop. The last item can be particularly helpful to instructors, so they know what the expectations of participants are, and can address those expectorations directly during the introduction and hands-on portions of the workshop.

The introductory presentation can also help orient participants to what will be covered in the workshop, and highlight common problems that participants run into as they work through the in-workshop activities. Here are some sample introductory workshop slides: http://bit.ly/2SDIu8M [25].

Most of the hands-on workshop activities provide a project and, where needed, data for the participant to use. If a participant has a project in mind, or their own data, we encourage them to use their own project or data if possible. Sometimes if their personal project is sufficiently complicated, they will be encouraged to tackle one of the activities provided to build their skill level before tackling their more ambitious personal project.

Once participants have started working on their activities, the instructor should lead the workshop in a "guide on the side" mode, typically wandering around the workshop space so that they are available for questions. They can also look at what the participants are doing and offer to help if they see someone struggling who may not be comfortable asking for assistance. Occasionally, if multiple participants are having the same type of problem, the instructor can briefly get everyone's attention and go into "sage on the stage" mode to give everyone the information they need to avoid the problem. Here is a link to a video that gives an example of how a flipped, active-learning workshop can begin, and then the transition from "sage on the stage" to "guide on the side": http://bit.ly/2yEIGIO [26].

Post-workshop assessment

The last slide for the in-class presentation at University of Victoria Libraries workshops is a link to a post-workshop assessment survey tool. Instructors are encouraged to ask participants to complete the survey. This is a more formal feedback instrument that is broad based and makes it easier to track trends over time, however the response rate has not been high [3].

Another less formal, but valuable method of feedback, is the informal after workshop chat with participants. Experience has shown that it pays to strike up conversations with workshop participants who either appeared to be enthusiastic, or students who appeared to be less engaged or frustrated to get their feedback. These conversations tend to highlight both the positive and negative aspects of a workshop and its delivery, and help the curators of a workshop's curriculum to focus their efforts on the areas in most need of improvement.

Peer feedback, combined with video review, can help instructors get a different perspective on their teaching strengths and weaknesses, and enables instructors to see how they perform as they watch the video at a later date. Some things that are not obvious in the moment for an instructor

can stand out when given feedback from a peer and watched on video.

Finally, self-evaluation can be an effective tool to find areas of improvement in the content of the workshop, the delivery of pre-workshop instruction, and the face-to-face workshop curriculum. This is particularly true when a workshop has gone especially well or especially poorly. Some questions that instructors can ask themselves are:

- Why did the workshop go well (or not) today?
- Was there something different about the group that positively or negatively impacted the workshop? Age of participants? Number of participants? Department of participants? Upcoming project that the tool being taught will help them with?
- Was there something about me that impacted how I delivered the workshop? Am I enthusiastic about the topic? Have I had a bad day? Has it been a long time since I've taught this workshop?

Taken together, formal survey feedback, informal conversations, peer and video feedback, and self-evaluation can help improve both the content and delivery of workshops.

Conclusions

The flipped, active-learning teaching method when used to create makerspace workshops can be an effective tool for introducing makerspace technologies to large numbers of novice makers. This is especially true for non-engineering students who drop in to the makerspace for workshops for general interest, or others who participate in makerspace workshops as part of for-credit classes. Key aspects of this pedagogy are:

1. Move as much instruction as possible into pre-workshop videos and exercises to free up as much face-to-face time for hands-on activities.
2. When creating a new workshop, start by identifying SMART learning outcomes that participants should leave the workshop knowing how to do: Specific, Measurable, Attainable, Relevant, and Time-based.
3. In-class activities should be active and contextual. As often as possible, students should be learning a new skill as they solve a problem or complete a for-credit assignment for one of their classes. Student choice and relevance motivate students in their learning.
4. Differentiation through pre-workshop instruction and modularized face-to-face activities allows learners to work at their own pace and choose what interests them, rather than a forced march tutorial/lecture.
5. Instructors should lead workshops as "guides on the side" rather than "sages on the stage." Learning is not a spectator sport [27].

This paper, and associated linked documents, serves a guide for creating and running active-learning workshops in academic makerspaces. For a full copy of the University of Victoria Libraries Digital Scholarship Commons, "Introduction to Creating & Teaching Flipped Active-Learning Workshops" workshop, please follow this link: http://bit.ly/2JF0g4i [28].

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