The New CGEMS – Preparing the Computer Graphics Educational Materials Source to Meet the Needs of Educators

Eike Falk Anderson[1,2] and Andrew Duchowski[3,2] and Fotis Liarokapis[4] and Adam Redford[1]

[1]The National Centre for Computer Animation, Bournemouth University, United Kingdom, [2]CGEMS
[3]School of Computing, Clemson University, SC, USA, [4]HCI Laboratory, Masaryk University, Brno, Czech Republic

Abstract

ACM SIGGRAPH and Eurographics are restarting CGEMS, the Computer Graphics Educational Materials Source, an on-line repository of curricular material for computer graphics education. In this context, the question that we ask ourselves is: "How can CGEMS best meet the needs of educators"? The aim of this forum is to provide the audience with an idea of the purpose of CGEMS – a source of educational materials for educators by educators – and to give them an opportunity to contribute their views and ideas towards shaping the new CGEMS. Towards this purpose, we have identified a number of issues to resolve, which the panel will put forward to the participants of the forum for discussion.

1. Introduction

The CGEMS concept was first introduced in 2002 [AFJ02] and CGEMS were active from 2004 to 2011 (Figure 1). A joint project by ACM SIGGRAPH and the Eurographics Association (https://education.siggraph.org/resources/cgems), CGEMS aims to create a repository of high-quality, peer-reviewed educational materials that provide extra value for educators, e.g. if they are designing a new course or try to integrate new elements into an existing course. One requirement for the acceptance of submissions is the provision of a rationale for the teaching materials, which sets CGEMS apart from most source repositories and on-line tutorials, and also makes CGEMS different from other publications on education.

This paper is organised as follows: We first describe potential shortcomings of CGEMS, addressing the scope of potential subject areas to be included in CGEMS, assessment and acceptance criteria of submitted materials and the form that such materials can take. We then propose possible solutions for these issues, presenting these in relation to different subject areas. We conclude with a brief discussion of future steps needed to restart CGEMS and a call for contribution of teaching materials to CGEMS.

2. CGEMS for Educators

The question we aim to explore is the following: "How can CGEMS best meet the needs of educators"?

CGEMS is not a publication reporting on educational developments, although the materials it presents include an educational rationale. CGEMS is supposed to serve educators, containing educational materials that are known to have been used successfully, so applying these materials should work, simplifying the task of selecting materials and presenting these to students while simultaneously avoiding pedagogical failures [BMT*11].

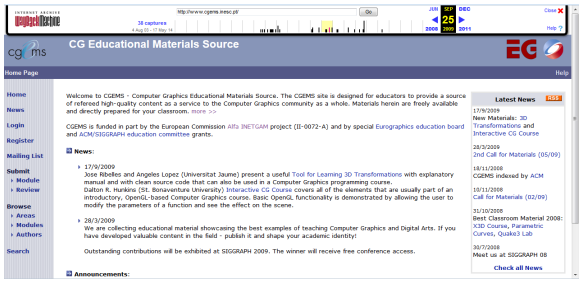

Figure 1: *The original CGEMS website is no longer active and contents have been migrated to the Eurographics Digital Library (http://diglib.eg.org/handle/10.2312/13864).*

2.1. What is the scope of CGEMS?

The question that needs to be answered first and foremost is what types (categories) of materials should be included in CGEMS? This is followed by the question of how they should then be presented to be both easily usable by and accessible to educators. The potential range of subjects for inclusion is vast [OAL*07] and may not be limited to computer graphics education topics. It could also extend to HCI in terms of multi-modal user interfaces and new technologies, or include the use of computer graphics in context [CC09].

Of the educational materials to be included in CGEMS, "prob-

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lem sets" are very similar in nature to the "Nifty Assignments" that have been featured by SIGCSE (ACM Special Interest Group for Computer Science Education) since 1999 (see http://nifty.stanford.edu/), but materials in CGEMS are not limited to assignments or to computer science materials in the context of computer graphics [CC10]. The scope of educational materials that CGEMS encompasses is much wider ranged and e.g. also includes whole programme syllabi (such as presented in the supplemental material to the programme description by Comninos et al. [CMA10]).

This leads to the question of how educational materials should be classified to help educators to navigate the information in the repository.

2.2. How are CGEMS Selected?

The peer-review workflow and editorial process was well described for the original CGEMS [AFJ02, FEJ04]. Submitted materials are forwarded to reviewers who are knowledgeable educators in the area covered by the submission to assess its suitability and to ensure that the best established processes of designing and creating teaching materials in the computer science CG context [HS06] have been followed.

In terms of educational materials, first and foremost is the requirement that materials in CGEMS should be useful. Problem sets and assignments should be meaningful [LWS07] and have similar attributes and make-up to the "nifty assignments" [Par04, Par07b] that are popular among computer science educators (and students). Results that have been achieved using CGEMS materials, i.e. successful learning, should also be reproducible [Boi16], and the challenge for CGEMS and for the reviewers selecting materials for inclusion in CGEMS is to ensure that these requirements are met.

What is a good description of an assignment for students easily lacks attributes that would be expected in an education paper (e.g. [And17]), adding nothing to the state of the art and lacking an evaluation of the work, and reviewers for CGEMS need to be aware of this. At the same time, the materials need to be reasonably mature and will ideally have been experienced by many students so one confidently can be assured of their suitability for use in education. This becomes especially important if the materials concerned are not just problem sets but complete courses or even degree programmes which may need to be reviewed by reviewers with diverse areas of expertise.

To achieve this, clear reviewer guidelines and selection criteria will have to be formulated and directly related to this, clear submission guidelines for educational materials that answer the question of what must educational materials include to help reviewers accurately assess their suitability for inclusion in CGEMS.

2.3. What Materials are Included with a CGEMS Item?

The width of the computer graphics domain creates a number of difficult challenges for the inclusion of educational materials that CGEMS needs to overcome.

2.3.1. Platform Specific Issues

Although the original CGEMS addressed technical barriers (e.g. in terms of supported platforms) by assessing these for materials as part of the review process, some assets included with the teaching materials (e.g. source-code based materials) were sometimes difficult to adapt to one's own teaching. Submissions were rarely platform-agnostic, meaning that to compile and run they would require a similar set-up to the systems used at the authors' institutions. CGEMS based on specific platforms and software systems (tools and applications) are also in danger of very quickly becoming out-dated (e.g. when API's or applications are replaced by new versions [FKU*10]) and consequently will no longer be usable/useful. Similarly, CGEMS that are too specific in regards to the systems required to employ them may have limited use.

This is especially problematic if the teaching material relates to or employs novel technologies, e.g. specific hardware devices for virtual reality (VR) or augmented reality (AR), where no unifying standards exist and different devices are used and accessed differently. Both technologies share similar hardware infrastructure and offer the ability to use sophisticated techniques to achieve better user interaction with teaching material and complex tools, but VR is completely replacing the teaching environment whereas AR enhances the real world by using computer-generated information. Both also allow learners to 'easier' understand complex procedures. In an ideal scenario, educators will be able to implement the learning materials and designs inside of their classroom according to how they have orchestrated their courses, but how such materials can be created in a device-independent manner remains an unanswered question, as is how materials that not simply use VR or AR but teach VR and AR should be presented in CGEMS.

Finding some way to overcome these problems would be a huge benefit, so how should this best be addressed?

2.3.2. Sample Solutions

Another potential issue is the question of whether CGEMS should include sample solutions for exercises and assignments. While clearly beneficial for educators who could use these sample solutions both to demonstrate to students what results should be achieved (e.g. by showing a running program to students) as well as to help with assessment (e.g. by comparing student submissions to the sample solutions), the inclusion of solutions may be counterproductive and there are a number of drawbacks that need to be considered.

Firstly, the inclusion of sample solutions would put these solutions on-line and freely accessible for all, including for students who may have been set assignments from CGEMS, which could tempt these students to simply look up the solution online [Par07a] rather than engaging their brains (a problem that is not particularly new). Secondly, solutions may not be immediately usable if they are prepared for a specific platform (i.e. the one used by the author), which may be different from the platform used by educators that use CGEMS materials (see 2.3.1).

As such, solutions should probably not be included in all CGEMS materials. Instead, however, could solutions be used as part of the review process and be included with submissions but excluded from accepted materials?

2.4. Can CGEMS Cater to Artists?

Given that computer graphics is multi-disciplinary, CGEMS content should go beyond STEM (Science, Technology, Engineering and Mathematics) and extend to STEAM (Science, Technology, Engineering, Arts and Mathematics) [Coo16], i.e. include the (digital) arts [Ebe97] as well. There have previously been attempts to provide curricular resources for digital arts [Ebe02]. Nevertheless, we do not yet know what would be the consequences of the inclusion of arts-based computer graphics materials. For instance, what would be most useful for educators as well as students in terms of downloadable teaching materials?

In computer arts education, students are often more concerned with the capabilities of the software they use rather than fundamental concepts [EME02], which exacerbates the implications of inclusion of assets or exemplars for use in tutorials/workshops in the teaching materials raised in the previous section (section 2.3), especially as many artists' tools receive regular updates/new versions that not only change the user interface but also often lack backwards compatibility in the file formats they employ.

The original CGEMS policy stated that "CGEMS is not in the market for graphics tools and therefore publication on the server should not constitute an implied endorsement or requirement to buy into a commercial product" [FEJ04], so ideally arts-based exercises and assessments (e.g. in modelling and animation) should concentrate on the underlying principles rather than the software used (e.g. even if a submitted exemplar, for instance, was created using a specific modelling and animation package, this should also be achievable with a different package). This, in addition to the challenge of how best to include arts related educational materials in CGEMS then also raises the question: how could/should this be achieved?

2.5. Educational Nomenclature – How can Ambiguity in CGEMS be Avoided?

The current trend in educational technologies sets up an extremely buoyant environment of small, low cost and limited function related applications that can be used in transforming, modernizing and internationalizing education. However, different terminology used in different education systems worldwide can be a barrier for educators when dealing with educational literature – it complicates understanding of the educational context of the work described in the literature and can lead to misunderstandings, e.g. what would be called a "course" in one place could be referred to as "unit" or "module" elsewhere, whereas the term "module" could have different meanings in different places and in different contexts.

Furthermore, authors who are familiar with their own country's education system but who lack awareness of differences between their own and other countries' education systems might omit important information that would be required to understand their work, as authors might assume some intricacies of their own education system to be general knowledge.

The question then is what CGEMS needs to provide for authors as well as educators intending to use CGEMS in terms of supplemental information on education systems and educational nomenclature, and how materials in CGEMS should be presented to avoid ambiguities and aid understanding.

3. The Way Forward for CGEMS

The questions and issues raised above are fairly complex and addressing them will likely also require complex solutions. The following sections describe a number of possible approaches and considerations that may provide directions towards achieving this aim.

3.1. Structuring CGEMS to Aid Educators

For presenting CGEMS materials to educators, in addition to classifying materials by the topic/subject domain they cover, some form of formal taxonomy of educational materials would be useful and desirable. One possible solution could be to classify CGEMS materials using the Four I's of educational activities [PA14], which provides a high-level classification of course elements and an indication of how they relate to one another.

This alone would still be rather limiting though, so additionally all materials included in CGEMS should provide some form of key information set of standardized information that quickly allows educators to not simply discover CGEMS materials that may be relevant to them but to also assess the usefulness of specific CGEMS submissions for their purposes, e.g.

- an indication of (student) contact hours & independent study hours covered by the materials to provide educators with an idea of how how the materials fit best into their own teaching sequence
- an indication of staff hours/effort (in terms of preparation, delivery & assessment) to provide a cost estimate for the use of the materials
- a list of other costs (equipment, etc.) where they arise
- an indication of credits (ECTS where this applies or something equivalent) if the materials are an assignment or course in order for educators to accurately judge the extent of the materials
- a description of the assessment (where appropriate/when the work includes assessment)

In combination with additional metadata (section 3.2), this may provide sufficient information about CGEMS materials, allowing them to find CGEMS materials that are useful for their purposes and to identify how and where these might be integrated into their own courses.

3.2. CGEMS Selection & Presentation

Metadata and additional descriptions and explanations of the materials submitted to CGEMS combine to aid editors and reviewers in the assessment of CGEMS. Their consideration should not only be part of the reviewer guidelines but will likely also be included in the acceptance criteria for CGEMS submissions. Included with the materials they also provide useful information about these to educators, helping them to identify materials that are suitable for their purposes.

To achieve this, mandatory information that might have to be included with CGEMS are:

- A statement of intended learning outcomes that students should demonstrate after being exposed to/having used the materials (and pre-requisite/co-requisite knowledge they would need to have for the materials to be understood).

Table 1: *CGEMS metadata in tabular format.*

Summary	What is the CGEM about, what do students learn?
Learning Outcomes	What should students who complete this assignment be able to explain, describe, implement, etc. (using active verbs from Bloom's taxonomy)?
Classification(s)	What is he curricular topic addressed by this assignment (e.g., Animation, Fundamentals, Modeling, etc.; there could be overlap among several.)
Audience	What is the assignment's curricular level (e.g., CS1, CS2, junior, senior, etc.)?
Dependencies	What is students' required prior knowledge, what else must be in place for students to carry out the assignment?
Prerequisites	Does this assignment build on any other assignments, e.g., is it a module in a sequence?
Strengths	What do (you think) students like about this assignment?
Weaknesses	What do (you think) students dislike about this assignment?
Variants	Are there any variants students can explore?
Assessment	What are the assessment criteria?

- Some form of (brief) evaluation of the application of the materials in teaching, including student responses/feedback where possible – this evaluation would not have to be analytic and an informative description would likely be sufficient.
- An indication of student outcomes/results where appropriate (e.g. pass-/fail-rates), i.e. when the material includes assessment, e.g. to provide a measure of difficulty for the material.
- An indication of how the material would fit into a syllabus/educational context, such as courses or degree programmes (where this is possible) to simplify its adaptation.

As an example, Table 1 shows a possible tabular layout for CGEMS metadata, following SIGCSE's "Nifty Assignments" metadata. Such a table could be a required element of a CGEMS submission.

3.3. Keep CGEMS Platform/System Agnostic & Current

For educators developing CGEMS materials, one of the greatest challenges will be to ensure that the materials are (where possible) platform agnostic, i.e. that the materials will not depend on specific products or devices (hardware/software) to be usable. For instance, (graphics) programming exercises (even if samples are provided in a specific programming or shader language) should if possible not be set up to only work with a single language/development environment or with specific hardware (e.g. graphics cards), which may be quite difficult to achieve.

The solution is for the content of educational materials to focus on underlying principles and concepts, first and foremost ensuring that all learning requirements are satisfied. The exact make-up of such platform agnostic materials would then depend on the nature of the subject being addressed. For graphics programming it may require the use of a standard API and development environment (although then the question arises which API, programming language or development environment should be used – OpenGL and C/C++ might seem obvious choices for this, but this will require additional consideration), and similar requirements/restrictions would apply to arts related educational materials (section 3.4). For materials that use or teach the use of specific devices, such as AR/VR related materials, simple and robust as well as cost effective and easily extensible systems are preferable, and a focus on underlying algorithms and in the case of AR, concentrating on the tracking interface (e.g. a set of distinctive marker cards) and how this links real and digital information could allow the creation of device independent teaching materials.

It is important to realise that educational materials, once accepted in CGEMS may not remain static and may be subject to ongoing maintenance requiring a sustained commitment by authors. The longevity of teaching materials depends on the nature of the subject matter, the depth and level of detail in which it covers the subject, and how dependent it is on specific systems or software.

Related to this it may also be useful to include a set of "standard assets" (e.g. 3D models, textures etc.) in CGEMS that could be reused for different teaching activities and that would be applicable to different educational contexts or usable for the teaching of different subjects. The provision of such assets would allow students to concentrate their efforts on the task at hand without having to worry about the creation of these assets, and educators could use these assets in the design of their educational materials. It would then be necessary to ensure that the quality of those assets is sufficiently high, and that they are fit for the purpose required. The number of assets in the repository would by necessity have to be high enough to include assets that are suitable for a wide variety of different scenarios and usage requirements.

3.4. Include Arts Related Educational Materials in CGEMS

As teaching materials for educating artists for theoretical lectures, standard lecture notes are perfectly adequate, but it often helps to have a lot of annotated images to help explain the text. Notes and lecture slides should where possible refer to general key principles of the production pipeline, whereas video tutorials could go into more detail about software specific creation techniques. Especially for workshops on specific disciplines it is often better to provide video tutorials for the students to follow along, but these should be provided to complement the workshop and not as a replacement.

It is also necessary to provide students with any assets (e.g. models, texture files) that should be used but not created during the workshop. It is often good to also provide students with any supplementary material that is not covered in the workshops itself (or is not covered in sufficient detail). This could take the form of an extended video tutorial that covers the whole creation process of an asset, as it is almost always necessary to skip large parts of the creation process during a workshop in favour of providing the students with a pre-made asset and telling them that with enough time and effort they could produce said asset with the techniques they have just been shown.

In terms of platform/software independence, it would very likely

not be particularly challenging to create teaching materials that are platform/software independent. Most platforms and software packages can all achieve the same end result through slightly different methods and built-in tools, so how easily materials can be adapted to different educational scenarios would depend on the type of task being taught. Any assets presented to students should, where possible, be independent of any particular piece of software, and file formats that are widely used and essentially provide a de-facto (lowest common denominator) standard should be preferred, e.g. 3D model files could be *.obj* models or texture files could be *.tif* images. This will not always be possible for some areas of the 3D graphics production pipeline, as for instance shader setup is an area of production that is usually software specific and there are some areas of the pipeline that are more software specific than others (e.g. rigging).

3.5. A Glossary for Solving the Nomenclature Problem

Addressing the educational nomenclature problem is especially important in the case of CGEMS (e.g. even Table 1 includes terminology that may not be understood by all educators everywhere), as the educational materials that the repository provides are supposed to be easily adaptable and usable.

A possible solution would be the inclusion of a glossary for terms used in different education systems in CGEMS (which would first need to be developed) and the establishment of a common terminology for use in materials included in CGEMS. This in itself may be a substantive (not to say monumental) task that is clearly beyond the scope of CGEMS and the purview of the editors, and would require the support of the computer graphics education community who ideally should set up a working group to develop this glossary.

4. What comes Next for CGEMS – Future Steps

In this position paper we have presented the challenges that the revival of the CGEMS project poses. We have also proposed possible approaches to addressing these issues. The success of CGEMS will depend on the support of the computer graphics community in general and rely particularly on the support of computer graphics educators, and we welcome their suggestions and contributions.

We therefore call for volunteers and contributors to join the working group for the glossary and to serve as reviewers for CGEMS submissions.

Finally, CGEMS is a repository of computer graphics educational materials for educators, developed and contributed by educators and can only work if the community creates teaching materials and submits them for inclusion in CGEMS (to submit: https://srmv2.eg.org/COMFy/Conference/CGEM).

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