Collaboration-Based Learning Environments using Augmented Reality

by

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ABSTRACT

The developments of the "kinetic theory" of gases made within the last ten years have enabled it to account satisfactorily for many of the laws of gases. The mathematical deductions of Clausius, Maxwell and others, based upon the hypothesis of a gas composed of molecules acting upon each other at impact like perfectly elastic spheres, have furnished expressions for the laws of its elasticity, viscosity, conductivity for heat, diffusive power and other properties. For some of these laws we have experimental data of value in testing the validity of these deductions and assumptions. Next to the elasticity, perhaps the phenomena of the viscosity of gases are best adapted to investigation.[1]

Thesis supervisor: Stefan Marks
Title: Associate Professor

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[1]Text from Holman (1876): doi:10.2307/25138434.

Acknowledgments

Write your acknowledgments here.

Biographical Sketch

Silas Whitcomb Holman was born in Harvard, Massachusetts on January 20, 1856. He received his S.B. degree in Physics from MIT in 1876, and then joined the MIT Department of Physics as an Assistant. He became Instructor in Physics in 1880, Assistant Professor in 1882, Associate Professor in 1885, and Full Professor in 1893. Throughout this period, he struggled with increasingly severe rheumatoid arthritis. At length, he was defeated, becoming Professor Emeritus in 1897 and dying on April 1, 1900.

Holman's light burned brilliantly before his tragic and untimely death. He published extensively in thermal physics, and authored textbooks on precision measurement, fundamental mechanics, and other subjects. He established the original Heat Measurements Laboratory. Holman was a much admired teacher among both his students and his colleagues. The reports of his department and of the Institute itself refer to him frequently in the 1880's and 1890's, in tones that gradually shift from the greatest respect to the deepest sympathy.

Holman was a student of Professor Edward C. Pickering, then head of the Physics department. Holman himself became second in command of Physics, under Professor Charles R. Cross, some years later. Among Holman's students, several went on to distinguish themselves, including: the astronomer George E. Hale ('90) who organized the Yerkes and Mt. Wilson observatories and who designed the 200 inch telescope on Mt. Palomar; Charles G. Abbot ('94), also an astrophysicist and later Secretary of the Smithsonian Institution; and George K. Burgess ('96), later Director of the Bureau of Standards.

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Chapter 1

Introduction

In the Netflix animated series Cyberpunk: Edgerunners (**cyberpunk_2022**), the main character attends courses at a prestigious academy that uses advanced technology to boost education and performance. The students gather in a room with Virtual Reality (VR) headsets and connect to the lesson, which is taught by a holographic (and probably powered by artificial intelligence) tutor. The episode does not show the lesson itself (the entire system fails catastrophically when attacked by malware), but the brief scene highlights the vision many people have of a futuristic classroom, one guided by advanced technology and automatization.

forsler_2024<empty citation> propose the term "post-digital classroom" to identify the characteristics and trends in education present in a world beyond the adoption of digital technologies. The purpose of this classroom is not anymore to introduce new technologies to students, but to implement them as an essential factor of the learning process. The post-digital classroom is interconnected, social and global. In this scenario, learning goes beyond the physical classroom because it is based on creating relationships between concepts and developing valuable skills rather than acquiring knowledge. It is also a classroom where information is detached from the physical learning institute, and access to facts and sources is, ideally, immediate, ubiquitous and democratic.

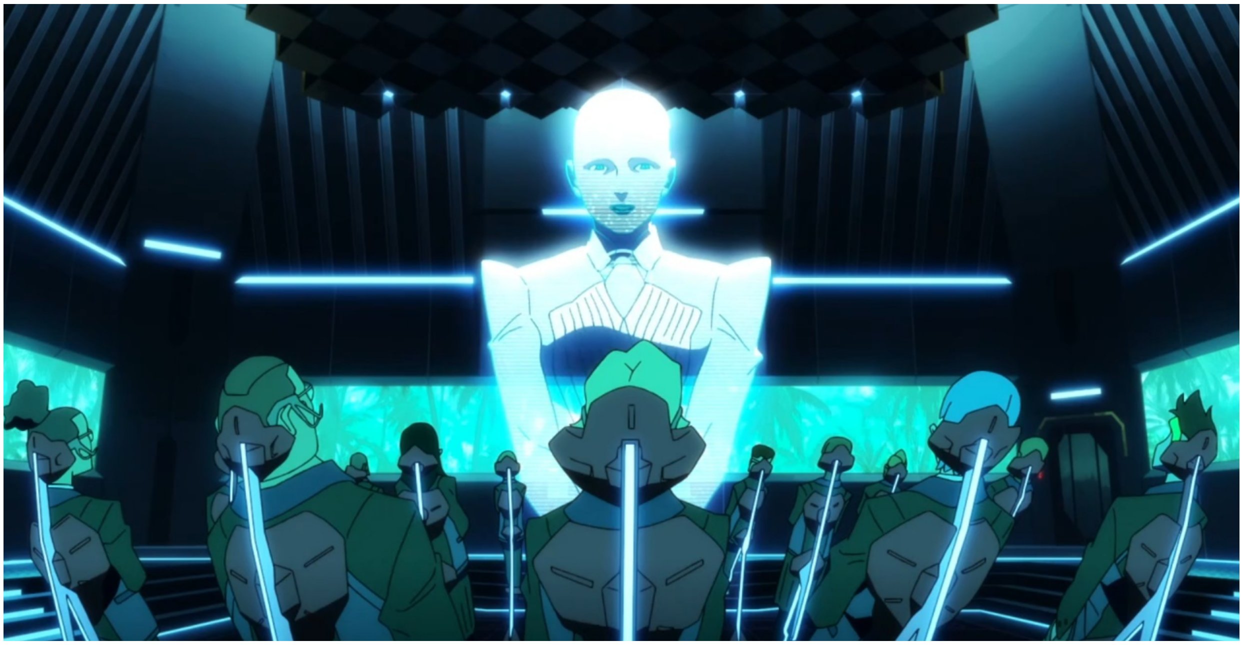
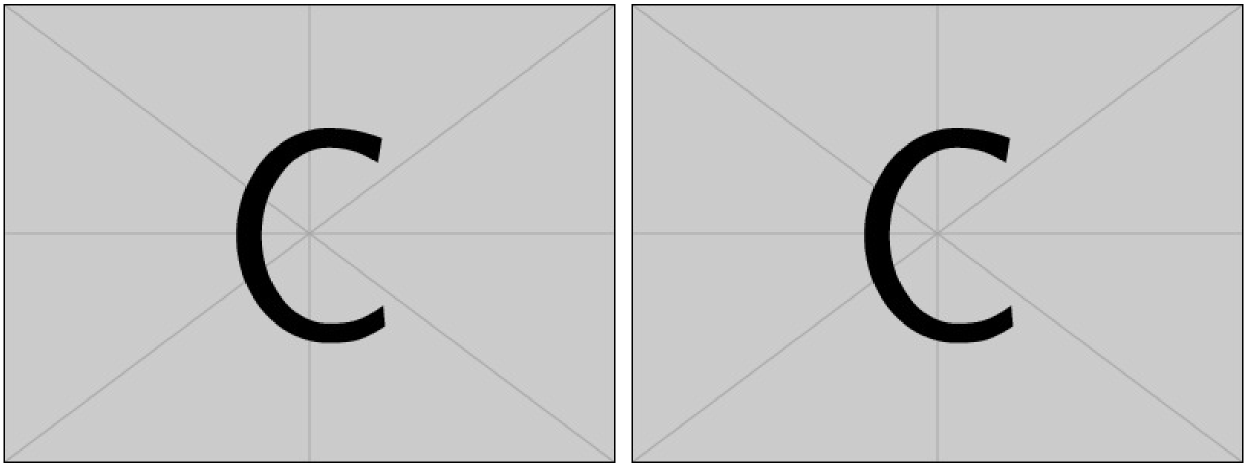


Figure 1.1: Virtual Classroom in Cyberpunk: Edgerunners



(a) First subfigure (b) Second subfigure

Figure 1.2: A figure with two subfigures: (a) first subfigure; (b) second subfigure.

1.1 Context

1.2 Research Structure

1.2.1 Research Questions

1.2.2 Scope and Limitations

1.3 Significance and Contributions

1.4 Document Structure

1.4.1 Subsection eqn. (??)

A subsubsection

$$L(\mathbf{A}) = \begin{pmatrix} \dfrac{\varphi}{(\varphi_1, \varepsilon_1)} & 0 & \ldots & \ldots & \ldots & 0 \\ \dfrac{\varphi k_{2,1}}{(\varphi_2, \varepsilon_1)} & \dfrac{\varphi}{(\varphi_2, \varepsilon_2)} & 0 & \ldots & \ldots & 0 \\ \dfrac{\varphi k_{3,1}}{(\varphi_3, \varepsilon_1)} & \dfrac{\varphi k_{3,2}}{(\varphi_3, \varepsilon_2)} & \dfrac{\varphi}{(\varphi_3, \varepsilon_3)} & 0 & \ldots & 0 \\ \vdots & \vdots & & \ddots & & \vdots \\ \dfrac{\varphi k_{n-1,1}}{(\varphi_{n-1}, \varepsilon_1)} & \dfrac{\varphi k_{n-1,2}}{(\varphi_{n-1}, \varepsilon_2)} & \ldots & \dfrac{\varphi k_{n-1,n-2}}{(\varphi_{n-1}, \varepsilon_{n-2})} & \dfrac{\varphi}{(\varphi_{n-1}, \varepsilon_{n-1})} & 0 \\ \dfrac{\varphi k_{n,1}}{(\varphi_n, \varepsilon_1)} & \dfrac{\varphi k_{n,2}}{(\varphi_n, \varepsilon_2)} & \ldots & \ldots & \dfrac{\varphi k_{n,n-1}}{(\varphi_n, \varepsilon_{n-1})} & \dfrac{\varphi}{(\varphi_n, \varepsilon_n)} \end{pmatrix} \tag{1.1}$$

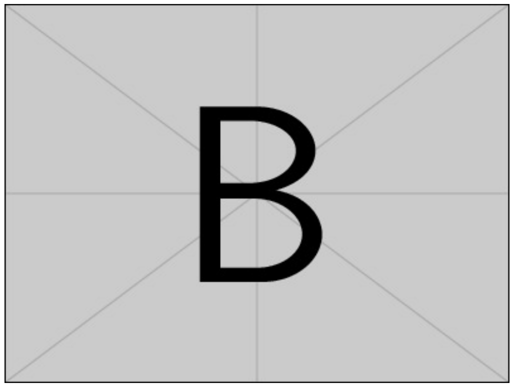


Figure 1.3: Caption text **GSL**.

1.5 Description our paradigm

1.5.1 Conversion to a metaheuristic

1.6 Other generalizations

1.6.1 The most general case

$$x\,\mathrm{Na(NH_4)HPO_4} \xrightarrow{\Delta} \mathrm{(NaPO_3)}_x + x\,\mathrm{NH_3}\uparrow + x\,\mathrm{H_2O} \tag{1.2}$$

$$^{234}_{90}\mathrm{Th} \longrightarrow {}^{0}_{-1}\beta + {}^{234}_{91}\mathrm{Pa} \tag{1.3}$$

$$\mathrm{SO_4}^{2-} + \mathrm{Ba}^{2+} \longrightarrow \mathrm{BaSO_4}\downarrow \tag{1.4}$$

$$\mathrm{Zn}^{2+} \underset{+2\,\mathrm{H}^+}{\overset{+2\,\mathrm{OH}^-}{\rightleftharpoons}} \underset{\text{amphoteric hydroxide}}{\mathrm{Zn(OH)_2}\downarrow} \underset{+2\,\mathrm{H}^+}{\overset{+2\,\mathrm{OH}^-}{\rightleftharpoons}} \underset{\text{tetrahydroxozincate}}{[\mathrm{Zn(OH)_4}]^{2-}} \tag{1.5}$$

These examples of chemical formulæ are copied directly from the documentation of the `mhchem` package, which was used to typeset them.

1.7 Baroclinic generation of vorticity

Substitution of the particle acceleration and application Stokes theorem leads to the *Kelvin-Bjerknes circulation theorem*, for $\rho \neq \text{fn}(p)$:

$$\frac{d\Gamma}{dt} = \frac{d}{dt}\int_{\mathcal{C}} \mathbf{u} \cdot d\mathbf{r} \tag{1.6}$$

$$= \int_{\mathcal{C}} \frac{D\mathbf{u}}{Dt} \cdot d\mathbf{r} + \underbrace{\int_{\mathcal{C}} \mathbf{u} \cdot d\left(\frac{d\mathbf{r}}{dt}\right)}_{=0} \tag{1.7}$$

$$= \iint_{\mathcal{S}} \nabla \times \frac{D\mathbf{u}}{Dt} \cdot d\mathbf{A} \tag{1.8}$$

$$= \iint_{\mathcal{S}} \nabla p \times \nabla \left(\frac{1}{\rho}\right) \cdot d\mathbf{A} \tag{1.9}$$

Baroclinic generation of vorticity accounts for the sea breeze and various other atmospheric currents in which temperature, rather than pressure, creates density gradients. Further, this phenomenon accounts for ocean currents in straits joining more and less saline seas, with surface currents flowing from the fresher to the saltier water and with bottom current going oppositely.

Nomenclature for Chapter 1

Roman letters

$\mathcal{C}$	material curve
$\mathbf{r}$	material position [m]
$\mathbf{u}$	velocity [m s^{-1}]

Greek letters

Γ	circulation [m^2 s^{-1}]
ρ	mass density [kg m^{-3}]
$\boldsymbol{\omega}$	vorticity [s^{-1}]

Table 1.1: The error function and complementary error function

x	erf(x)	erfc(x)	x	erf(x)	erfc(x)
0.00	0.00000	1.00000	1.10	0.88021	0.11980
0.05	0.05637	0.94363	1.20	0.91031	0.08969
0.10	0.11246	0.88754	1.30	0.93401	0.06599
0.15	0.16800	0.83200	1.40	0.95229	0.04771
0.20	0.22270	0.77730	1.50	0.96611	0.03389
0.30	0.32863	0.67137	1.60	0.97635	0.02365
0.40	0.42839	0.57161	1.70	0.98379	0.01621
0.50	0.52050	0.47950	1.80	0.98909	0.01091
0.60	0.60386	0.39614	1.8214	0.99000	0.01000
0.70	0.67780	0.32220	1.90	0.99279	0.00721
0.80	0.74210	0.25790	2.00	0.99532	0.00468
0.90	0.79691	0.20309	2.50	0.99959	0.00041
1.00	0.84270	0.15730	3.00	0.99998	0.00002

Appendix A

Code listing

This example uses the `listings` package.

```
function print_rate(kappa,xMin,xMax,npoints,option)
     local c = 1-kappa*kappa
     local croot = (1-kappa*kappa)^(1/2)
     local logx = math.log(xMin)
     local psi = 0

     local xstep = (math.log(xMax)-math.log(xMin))/(npoints-1)

     arg0 = math.sqrt(xMin/c)
     psi0 = (1/c)*math.exp((kappa*arg0)^2)*(erfc(kappa*arg0)-erfc(arg0))

     if option~=[[]] then
       tex.sprint("\\addplot+["..option.."] coordinates{")
       -- addplot+ for color cycle to work
     else
       tex.sprint("\\addplot+ coordinates{")
     end
     tex.sprint("("..xMin..","..psi0..")")

     for i=1, (npoints-1) do
       x = math.exp(logx + xstep)
       arg = math.sqrt(x/c)
       karg = kappa*arg
       if karg<5 then
     -- this break compensates for exp(karg^2), which multiplies the error in the erf approximation...
          logpsi = -math.log(croot) + karg^2 + math.log(erfc(karg)-erfc(arg))
          psi = math.exp(logpsi)
       else
```

```
          psi = (1/(karg) - 1/(2*(karg^3)) + 3/(4*(arg^5)) )/(1.77245385*croot)
          -- this is the large x asymptote of the reaction rate
       end
       logx = math.log(x)
       tex.sprint("("..x..","..psi..")")
     end
     tex.sprint("}")
end
\end{luacode*}
```

Appendix B

One-term coefficients for heat conduction

B.1 A multipage table of numbers

This example uses the `longtable` package: $\theta = A_1 f_1 \exp(-\lambda_1^2 \mathrm{Fo})$, $\overline{\theta} = D_1 \exp(-\lambda_1^2 \mathrm{Fo})$.

Table B.1: One-term coefficients for one-dimensional heat conduction with a convective boundary condition. Data follow H. D. Baehr and K. Stephan **baehr1998**.

Bi	*Plate*			*Cylinder*			*Sphere*		
	λ_1	A_1	D_1	λ_1	A_1	D_1	λ_1	A_1	D_1
0.01	0.09983	1.0017	1.0000	0.14124	1.0025	1.0000	0.17303	1.0030	1.0000
0.02	0.14095	1.0033	1.0000	0.19950	1.0050	1.0000	0.24446	1.0060	1.0000
0.03	0.17234	1.0049	1.0000	0.24403	1.0075	1.0000	0.29910	1.0090	1.0000
0.04	0.19868	1.0066	1.0000	0.28143	1.0099	1.0000	0.34503	1.0120	1.0000
0.05	0.22176	1.0082	0.9999	0.31426	1.0124	0.9999	0.38537	1.0150	1.0000
0.06	0.24253	1.0098	0.9999	0.34383	1.0148	0.9999	0.42173	1.0179	0.9999
0.07	0.26153	1.0114	0.9999	0.37092	1.0173	0.9999	0.45506	1.0209	0.9999
0.08	0.27913	1.0130	0.9999	0.39603	1.0197	0.9999	0.48600	1.0239	0.9999
0.09	0.29557	1.0145	0.9998	0.41954	1.0222	0.9998	0.51497	1.0268	0.9999
0.10	0.31105	1.0161	0.9998	0.44168	1.0246	0.9998	0.54228	1.0298	0.9998
0.15	0.37788	1.0237	0.9995	0.53761	1.0365	0.9995	0.66086	1.0445	0.9996
0.20	0.43284	1.0311	0.9992	0.61697	1.0483	0.9992	0.75931	1.0592	0.9993
0.25	0.48009	1.0382	0.9988	0.68559	1.0598	0.9988	0.84473	1.0737	0.9990
0.30	0.52179	1.0450	0.9983	0.74646	1.0712	0.9983	0.92079	1.0880	0.9985
0.40	0.59324	1.0580	0.9971	0.85158	1.0931	0.9970	1.05279	1.1164	0.9974
0.50	0.65327	1.0701	0.9956	0.94077	1.1143	0.9954	1.16556	1.1441	0.9960
0.60	0.70507	1.0814	0.9940	1.01844	1.1345	0.9936	1.26440	1.1713	0.9944
0.70	0.75056	1.0918	0.9922	1.08725	1.1539	0.9916	1.35252	1.1978	0.9925
0.80	0.79103	1.1016	0.9903	1.14897	1.1724	0.9893	1.43203	1.2236	0.9904
0.90	0.82740	1.1107	0.9882	1.20484	1.1902	0.9869	1.50442	1.2488	0.9880
1.00	0.86033	1.1191	0.9861	1.25578	1.2071	0.9843	1.57080	1.2732	0.9855
1.10	0.89035	1.1270	0.9839	1.30251	1.2232	0.9815	1.63199	1.2970	0.9828
1.20	0.91785	1.1344	0.9817	1.34558	1.2387	0.9787	1.68868	1.3201	0.9800
1.30	0.94316	1.1412	0.9794	1.38543	1.2533	0.9757	1.74140	1.3424	0.9770
1.40	0.96655	1.1477	0.9771	1.42246	1.2673	0.9727	1.79058	1.3640	0.9739
1.50	0.98824	1.1537	0.9748	1.45695	1.2807	0.9696	1.83660	1.3850	0.9707

Table B.1: (continued)

Bi	*Plate* λ_1	*Plate* A_1	*Plate* D_1	*Cylinder* λ_1	*Cylinder* A_1	*Cylinder* D_1	*Sphere* λ_1	*Sphere* A_1	*Sphere* D_1
1.60	1.00842	1.1593	0.9726	1.48917	1.2934	0.9665	1.87976	1.4052	0.9674
1.70	1.02725	1.1645	0.9703	1.51936	1.3055	0.9633	1.92035	1.4247	0.9640
1.80	1.04486	1.1695	0.9680	1.54769	1.3170	0.9601	1.95857	1.4436	0.9605
1.90	1.06136	1.1741	0.9658	1.57434	1.3279	0.9569	1.99465	1.4618	0.9570
2.00	1.07687	1.1785	0.9635	1.59945	1.3384	0.9537	2.02876	1.4793	0.9534
2.20	1.10524	1.1864	0.9592	1.64557	1.3578	0.9472	2.09166	1.5125	0.9462
2.40	1.13056	1.1934	0.9549	1.68691	1.3754	0.9408	2.14834	1.5433	0.9389
2.60	1.15330	1.1997	0.9509	1.72418	1.3914	0.9345	2.19967	1.5718	0.9316
2.80	1.17383	1.2052	0.9469	1.75794	1.4059	0.9284	2.24633	1.5982	0.9243
3.00	1.19246	1.2102	0.9431	1.78866	1.4191	0.9224	2.28893	1.6227	0.9171
3.50	1.23227	1.2206	0.9343	1.85449	1.4473	0.9081	2.38064	1.6761	0.8995
4.00	1.26459	1.2287	0.9264	1.90808	1.4698	0.8950	2.45564	1.7202	0.8830
4.50	1.29134	1.2351	0.9193	1.95248	1.4880	0.8830	2.51795	1.7567	0.8675
5.00	1.31384	1.2402	0.9130	1.98981	1.5029	0.8721	2.57043	1.7870	0.8533
6.00	1.34955	1.2479	0.9021	2.04901	1.5253	0.8532	2.65366	1.8338	0.8281
7.00	1.37662	1.2532	0.8932	2.09373	1.5411	0.8375	2.71646	1.8673	0.8069
8.00	1.39782	1.2570	0.8858	2.12864	1.5526	0.8244	2.76536	1.8920	0.7889
9.00	1.41487	1.2598	0.8796	2.15661	1.5611	0.8133	2.80443	1.9106	0.7737
10.00	1.42887	1.2620	0.8743	2.17950	1.5677	0.8039	2.83630	1.9249	0.7607
12.00	1.45050	1.2650	0.8658	2.21468	1.5769	0.7887	2.88509	1.9450	0.7397
14.00	1.46643	1.2669	0.8592	2.24044	1.5828	0.7770	2.92060	1.9581	0.7236
16.00	1.47864	1.2683	0.8541	2.26008	1.5869	0.7678	2.94756	1.9670	0.7109
18.00	1.48830	1.2692	0.8499	2.27556	1.5898	0.7603	2.96871	1.9734	0.7007
20.00	1.49613	1.2699	0.8464	2.28805	1.5919	0.7542	2.98572	1.9781	0.6922
25.00	1.51045	1.2710	0.8400	2.31080	1.5954	0.7427	3.01656	1.9856	0.6766
30.00	1.52017	1.2717	0.8355	2.32614	1.5973	0.7348	3.03724	1.9898	0.6658
35.00	1.52719	1.2721	0.8322	2.33719	1.5985	0.7290	3.05207	1.9924	0.6579
40.00	1.53250	1.2723	0.8296	2.34552	1.5993	0.7246	3.06321	1.9942	0.6519
50.00	1.54001	1.2727	0.8260	2.35724	1.6002	0.7183	3.07884	1.9962	0.6434
60.00	1.54505	1.2728	0.8235	2.36510	1.6007	0.7140	3.08928	1.9974	0.6376
80.00	1.55141	1.2730	0.8204	2.37496	1.6013	0.7085	3.10234	1.9985	0.6303
100.00	1.55525	1.2731	0.8185	2.38090	1.6015	0.7052	3.11019	1.9990	0.6259
200.00	1.56298	1.2732	0.8146	2.39283	1.6019	0.6985	3.12589	1.9998	0.6170
∞	1.57080	1.2732	0.8106	2.40483	1.6020	0.6917	3.14159	2.0000	0.6079